NEW EXPERIMENTS
AND
OBSERVATIONS
ON
ELECTRICITY.
MADE AT
PHILADELPHIA in AMERICA.

BY

BENJAMIN FRANKLIN, Eſq;

AND

Communicated in SEVERAL LETTERS
To PETER COLLINSON, Eſq; of *London*, F.R.S.

PART I.

The THIRD EDITION.

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BRITISH MUSEUM

The PREFACE.

IT may be neceſſary to acquaint the Reader, that the following obſervations and experiments were not drawn up with a view to their being made publick, but were communicated at different times, and moſt of them in letters wrote on various topicks, as matters only of private amuſement.

But ſome perſons to whom they were read, and who had themſelves been converſant in electrical diſquiſitions, were of opinion, they contained ſo many curious and intereſting particulars relative to this affair, that it would be doing a kind of injuſtice to the publick, to confine them ſolely to the limits of a private acquaintance.

The Editor was therefore prevailed upon to commit ſuch extracts of letters, and other detach'd pieces as were in his hands to the preſs, without waiting for the ingenious author's permiſſion ſo to do; and this was done with the leſs heſitation, as it was apprehended the author's engagements in other affairs would ſcarce afford him leiſure to give the publick his reflections and experiments on the ſubject, finiſhed with that care and preciſion, of which the treatiſe before us ſhews he is alike ſtudious and capable. He was only apprized of the ſtep that had been thus taken, while the firſt ſheets were in the preſs, and time enough for him to tranſmit ſome farther remarks, together with a few corrections and additions, which are placed at the end, and may be conſulted in the peruſal.

The experiments which our author relates are moſt of them peculiar to himſelf; they are conducted with judgment, and the inferences from them plain and concluſive; though ſometimes propoſed under the terms of ſuppoſitions and conjectures.

And indeed the ſcene he opens, ſtrikes us with a pleaſing aſtoniſhment, while he conducts us by a train of facts and judicious reflections, to a probable cauſe of thoſe phænomena, which are at once the moſt awful, and, hitherto, accounted for with the leaſt veriſimilitude.

He exhibits to our conſideration, an inviſible, ſubtile matter, diſſeminated through all nature in various proportions, equally unobſerved, and, whilſt all thoſe bodies to which it peculiarly adheres are alike charged with it, inoffenſive.

He ſhews, however, that if an unequal diſtribution is by any means brought about; if there is a coacervation in one part of ſpace, a leſs proportion, vacuity, or want, in another; by the near approach of a body capable of conducting the coacervated part to the emptier ſpace, it becomes perhaps the moſt formidable and irreſiſtible agent in the univerſe. Animals are in an inſtant ſtruck breathleſs, bodies almoſt impervious by any force yet known, are perforated, and metals fuſed by it, in a moment.

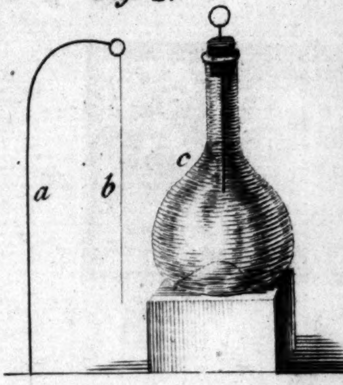
From the ſimilar effects of lightening and electricity our author has been led to make ſome probable conjectures on the cauſe of the former; and, at the ſame time, to propoſe ſome rational experiments in order to ſecure ourſelves, and thoſe things on which its force is often directed, from its pernicious effects; a circumſtance of no ſmall importance to the publick, and therefore worthy of the utmoſt attention.

It has, indeed, been of late the faſhion to aſcribe every grand or unuſual operation of nature, ſuch as lightening and earthquakes, to electricity; not, as one would imagine, from the manner of reaſoning on theſe occaſions, that the authors of theſe ſchemes have, diſcovered any connection betwixt the cauſe and effect, or ſaw in what manner they were related; but, as it would ſeem, merely becauſe they were unacquainted with any other agent, of which it could not poſitively be ſaid the connection was impoſſible.

But of theſe, and many other intereſting circumſtances, the reader will be more ſatisfactorily informed in the following letters, to which he is therefore referred by

The EDITOR.

Fig. I.



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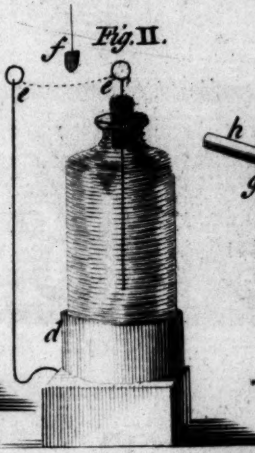

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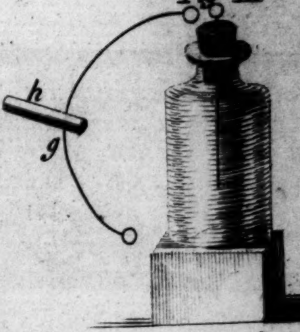

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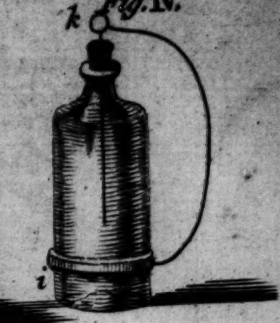
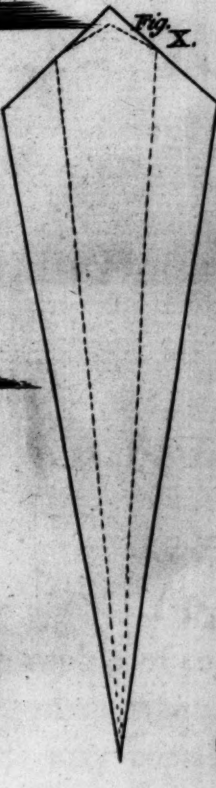


Fig. X.



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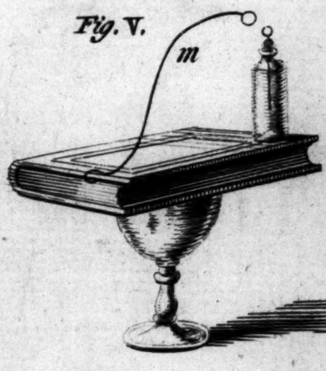

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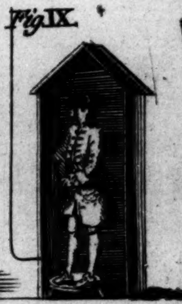

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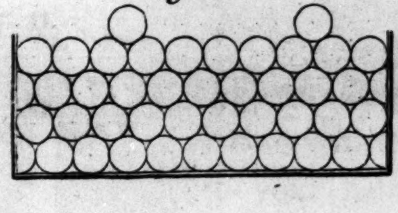

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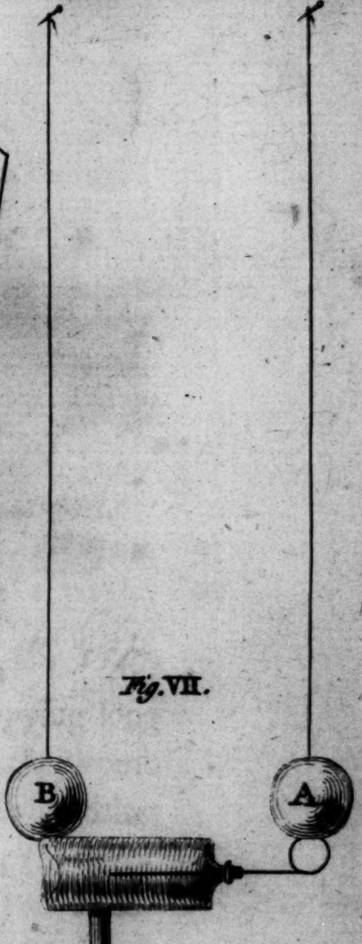

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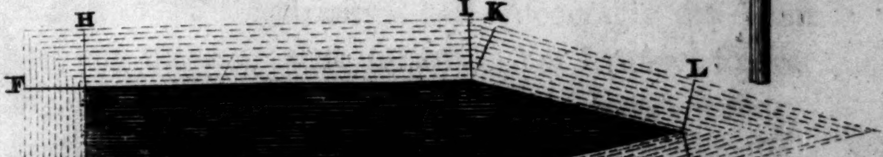

T. Jefferys sculp.

LETTER I.

FROM

Mr BENJ. FRANKLIN, in *Philadelphia*,

TO

PETER COLLINSON, Eſq; F. R. S. *London*.

SIR, *July* 28, 1747.

THE neceſſary trouble of copying long letters, which perhaps when they come to your hands may contain nothing new, or worth your reading (ſo quick is the progreſs made with you in Electricity) half diſcourages me from writing any more on that ſubject. Yet I cannot forbear adding a few obſervations on M. *Muſchenbroek*'s wonder-bottle.

1. The non-electric contain'd in the bottle differs when electriſed from a non-electric electriſed out of the bottle, in this: that the electrical fire of the latter is accumulated *on its ſurface*, and forms an electrical atmoſphere round it of conſiderable extent: but the electrical fire is crowded *into the ſubſtance* of the former, the glaſs confining it.

2. At the ſame time that the wire and top of the bottle, &c. is electriſed *poſitively* or *plus*, the bottom of the bottle is electriſed *negatively* or *minus*, in exact proportion: *i. e.* whatever quantity of electrical fire is thrown in at top, an equal quantity goes out of the bottom. To underſtand this, ſuppoſe the common quantity of electricity in each part of the bottle, before the operation begins, is equal to 20; and at every ſtroke of the tube, ſuppoſe a quantity equal to 1 is thrown in; then, after the firſt ſtroke, the quantity contain'd in the wire and upper part of the bottle will be 21, in the bottom 19. After the ſecond, the upper part will have 22, the lower 18, and ſo on 'till after 20 ſtrokes, the upper part will have a quantity of electrical fire equal to 40, the lower part none: and then the operation ends: for no more can be thrown into the upper part, when no more can be driven out of the lower part. If you attempt to throw more in, it is ſpued back through the wire, or flies out in loud cracks through the ſides of the bottle.

Is not Glaſs impervious.

3. The equilibrium cannot be reſtored in the bottle by *inward* communication or contact of the parts; but it muſt be done by a communication form'd *without* the bottle,

bottle between the top and bottom, by ſome non-electric, touching both at the ſame time; in which caſe it is reſtored with a violence and quickneſs inexpreſſible; or, touching each alternately, in which caſe the equilibrium is reſtored by degrees.

4. As no more electrical fire can be thrown into the top of the bottle, when all is driven out of the bottom, ſo in a bottle not yet electriſed, none can be thrown into the top, when none *can* get out at the bottom; which happens either when the bottom is too thick, or when the bottle is placed on an electric *per ſe*. Again, when the bottle is electriſed, but little of the electrical fire can be *drawn out* from the top, by touching the wire, unleſs an equal quantity can at the ſame time *get in* at the bottom. Thus, place an electriſed bottle on clean glaſs or dry wax, and you will not, by touching the wire, get out the fire from the top. Place it on a non-electric, and touch the wire, you will get it out in a ſhort time; but ſooneſt when you form a direct communication as above.

So wonderfully are theſe two ſtates of Electricity, the *plus* and *minus* combined and balanced in this miraculous bottle! ſituated and related to each other in a manner that I can by no means comprehend! If it were poſſible that a bottle ſhould in one part contain a quantity of air ſtrongly compreſt, and in another part a perfect vacuum, we know the equilibrium would be inſtantly reſtored *within*. But here we have a bottle containing at the ſame time a *plenum* of electrical fire, and a *vacuum* of the ſame fire; and yet

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the equilibrium cannot be reſtored between them but by a communication *without !* though the *plenum* preſſes violently to expand, and the hungry vacuum ſeems to attract as violently in order to be filled.

5. The ſhock to the nerves (or convulſion rather) is occaſioned by the ſudden paſſing of the fire through the body in its way from the top to the bottom of the bottle. The fire takes the ſhorteſt courſe, as Mr *Watſon* juſtly obſerves: But it does not appear, from experiment, that, in order for a perſon to be ſhocked, a communication with the floor is neceſſary; for he that holds the bottle with one hand, and touches the wire with the other, will be ſhock'd as much, though his ſhoes be dry, or even ſtanding on wax, as otherwiſe. And on the touch of the wire (or of the gun-barrel, which is the ſame thing) the fire does not proceed from the touching finger to the wire, as is ſuppoſed, but from the wire to the finger, and paſſes through the body to the other hand, and ſo into the bottom of the bottle.

EXPERIMENTS *confirming the above.*

EXPERIMENT I.

Place an electriſed phial on wax; a ſmall cork-ball ſuſpended by a dry ſilk-thread held in your hand, and brought near to the wire, will firſt be attracted, and then repelled: when in this ſtate of repellency, ſink your hand, that the ball may be brought towards the bottom of the bottle; it will there be inſtantly and ſtrongly attracted, 'till it has parted with its fire.

If the bottle had an electrical atmoſphere, as well as the wire, an electrified cork would be repelled from one as well as from the other.

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EXPERIMENT II.

FIG. 1. From a bent wire (*a*) ſticking in the table, let a ſmall linen thread (*b*) hang down within half an inch of the electriſed phial (*c*). Touch the wire of the phial repeatedly with your finger, and at every touch you will ſee the thread inſtantly attracted by the bottle. (This is beſt done by a vinegar cruet, or ſome ſuch belly'd bottle). As ſoon as you draw any fire out from the upper part by touching the wire, the lower part of the bottle draws an equal quantity in by the thread.

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EXPERIMENT III.

FIG. 2. Fix a wire in the lead, with which the bottom of the bottle is armed (*d*) ſo as that bending upwards, its ring-end may be level with the top or ring-end of the wire in the cork (*e*), and at three or four inches diſtance. Then electriciſe the bottle, and place it on wax. If a cork ſuſpended by a ſilk thread (*f*) hang between theſe two wires, it will play inceſſantly from one to the other, 'till the bottle is no longer electriſed; that is, it fetches and carries fire from the top to the bottom of the bottle, 'till the equilibrium is reſtored.

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EXPERIMENT IV.

FIG. 3. Place an electriſed phial on wax; take a wire *(g)* in form of a *C*, the ends at ſuch a diſtance when bent, as that the upper may touch the wire of the bottle, when the lower touches the bottom: ſtick the outer part on a ſtick of ſealing-wax (*h*), which will ſerve as a handle. Then apply the lower end to the bottom of the bottle, and gradually bring the upper-end near the wire in the cork. The conſequence is, ſpark follows ſpark till the equilibrium is reſtored. Touch the top firſt, and on approaching the bottom with the other end, you have a conſtant ſtream of fire, from the wire entering the bottle. Touch the top and bottom together, and the equilibrium will ſoon be reſtored, but ſilently and imperceptibly; the crooked wire forming the communication.

b. 5.

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EXPERIMENT V.

FIG. 4. Let a ring of thin lead or paper ſurround a bottle (*i*), even at ſome diſtance from or above the bottom. From that ring let a wire proceed up, till it touch the wire of the cork *(k)*. A bottle ſo fixt cannot by any means be electriſed: the equilibrium is never deſtroyed: for while the communication between the upper and lower parts of the bottle is continued by the outſide wire, the fire only circulates: what is driven out at bottom, is conſtantly ſupply'd from the top. Hence a bottle cannot be electriſed that is foul or moiſt on the outſide.

b. 5.

EXPERIMENT VI.

Place a man on a cake of wax, and preſent him the wire of the electrified phial to touch, you ſtanding on the floor, and holding it in your hand. As often as he touches it, he will be electrified *plus*; and any one ſtanding on the floor may draw a ſpark from him. The fire in this experiment paſſes out of the wire into him; and at the ſame time out of your hand into the bottom of the bottle.

O. S

EXPERIMENT VII.

Give him the electrical phial to hold; and do you touch the wire; as often as you touch it he will be electrified *minus*, and may draw a ſpark from any one ſtanding on the floor. The fire now paſſes from the wire to you, and from him into the bottom of the bottle.

O. S

EXPERIMENT VIII.

Lay two books on two glaſſes, back towards back, two or three inches diſtant. Set the electrified phial on one, and then touch the wire; that book will be electrified *minus*; the electrical fire being drawn out of it by the bottom of the bottle. Take off the bottle, and holding it in your hand, touch the other with the wire; that book will be electriſed *plus*; the fire paſſing into it from the wire, and the bottle at the ſame time ſupply'd from your hand. A ſuſpended ſmall cork-ball will play between theſe books 'till the equilibrium is reſtored.

O. S

EXPERIMENT IX.

When a body is electriſed *plus* it will repel an electrified feather or ſmall cork-ball. When *minus* (or when in the common ſtate) it will attract them, but ſtronger when *minus* than when in the common ſtate, the difference being greater.

EXPERIMENT X.

Tho', as in EXPER. VI. a man ſtanding on wax may be electriſed a number of times, by repeatedly touching the wire of an electriſed bottle (held in the hand of one ſtanding on the floor) he receiving the fire from the wire each time: yet holding it in his own hand, and touching the wire, tho' he draws a ſtrong ſpark, and is violently ſhock'd, no Electricity remains in him; the fire only paſſing thro' him from the upper to the lower part of the bottle. Obſerve, before the ſhock, to let ſome one on the floor touch him to reſtore the equilibrium in his body; for in taking hold of the bottom of the bottle, he ſometimes becomes a little electriſed *minus*, which will continue after the ſhock; as would alſo any *plus* Electricity, which he might have given him before the ſhock. For, reſtoring the equilibrium in the bottle does not at all affect the Electricity in the man thro' whom the fire paſſes; that Electricity is neither increaſed nor diminiſhed.

EXPERIMENT XI.

The paſſing of the electrical fire from the upper to the lower part of the bottle, to reſtore the equilibrium, is render'd ſtrongly viſible by the following pretty experiment.

ment. Take a book whoſe cover is filletted with gold, bend a wire of eight or ten inches long in the form of (*m*) Fig. 5. ſlip it on the end of the cover of the book over the old line, ſo as that the ſhoulder of it may preſs upon one end of the gold line, the ring up, but leaning towards the other end of the book. Lay the book on a glaſs or wax; and on the other end of the gold lines, ſet the bottle electriſed; then bend the ſpringing wire, by preſſing it with a ſtick of wax till its ring approaches the ring of the bottle wire; inſtantly there is a ſtrong ſpark and ſtroke, and the whole line of gold, which completes the communication between the top and bottom of the bottle, will appear a vivid flame, like the ſharpeſt lightning. The cloſer the contact between the ſhoulder of the wire, and the gold at one end of the line, and between the bottom of the bottle and the gold at the other end, the better the experiment ſucceeds. The room ſhould be darkened. If you would have the whole filletting round the cover appear in fire at once, let the bottle and wire touch the gold in the diagonally oppoſite corners.

I am, &c.

B. FRANKLIN.

LETTER II.

FROM

Mr BENJ. FRANKLIN, in *Philadelphia*,

TO

PETER COLLINSON, Eſq; F. R. S. *London*.

SIR, *Sept.* 1, 1747.

IN my laſt I informed you that, in purſuing our electrical enquiries, we had obſerved ſome particular Phænomena, which we looked upon to be new, and of which I promiſed to give you ſome account, tho' I apprehended they might poſſibly not be new to you, as ſo many hands are daily employ'd in electrical experiments on your ſide the water, ſome or other of which would probably hit on the ſame obſervations.

The firſt is the wonderful effect of pointed bodies, both in *drawing off* and *throwing off* the electrical fire. For example: Place an iron ſhot of three or four inches diameter on the mouth of a clean dry glaſs bottle. By a fine ſilken thread from the cieling, right over the mouth of the bottle, ſuſpend a ſmall cork-ball, about the bigneſs of a marble; the

O. S.

thread of ſuch a length, as that the cork-ball may reſt againſt the ſide of the ſhot. Electrify the ſhot, and the ball will be repelled to the diſtance of four or five inches, more or leſs, according to the quantity of Electricity.—— When in this ſtate, if you preſent to the ſhot the point of a long ſlender ſharp bodkin, at ſix or eight inches diſtance, the repellency is inſtantly deſtroy'd, and the cork flies to the ſhot. A blunt body muſt be brought within an inch, and draw a ſpark, to produce the ſame effect. To prove that the electrical fire is *drawn off* by the point, if you take the blade of the bodkin out of the wooden handle, and fix it in a ſtick of ſealing wax, and then preſent it at the diſtance aforeſaid, or if you bring it very near, no ſuch effect follows; but ſliding one finger along the wax till you touch the blade, and the ball flies to the ſhot immediately. —If you preſent the point in the dark, you will ſee, ſometimes at a foot diſtance, and more, a light gather upon it like that of a fire-fly or glow-worm; the leſs ſharp the point, the nearer you muſt bring it to obſerve the light; and at whatever diſtance you ſee the light, you may draw off the electrical fire, and deſtroy the repellency.—If a cork-ball ſo ſuſpended be repelled by the tube, and a point be preſented quick to it, tho' at a conſiderable diſtance, 'tis ſurprizing to ſee how ſuddenly it flies back to the tube. Points of wood will do as well as thoſe of iron, provided the wood is not dry; for perfectly dry wood will no more conduct Electricity than ſealing wax.

To ſhew that points will *throw off* as well as *draw off* the electrical fire; lay a long ſharp needle upon the ſhot, and you cannot electriſe the ſhot, ſo as to make it repel the cork-ball.—Or fix a needle to the end of a ſuſpended gun-barrel, or iron rod, ſo as to point beyond it like a little bayonet; and while it remains there, the gun-barrel, or rod, cannot by applying the tube to the other end be electriſed ſo as to give a ſpark, the fire continually running out ſilently at the point. In the dark you may ſee it make the ſame appearance as it does in the caſe beforementioned.

The repellency between the cork-ball and the ſhot is likewiſe deſtroy'd. 1. By ſifting fine ſand on it; this does it gradually. 2. By breathing on it. 3. By making a ſmoke about it from burning wood.* 4. By candle light, even tho' the candle is at a foot diſtance: theſe do it ſuddenly.—The light of a bright coal from a wood fire; and the light of red-hot iron do it likewiſe; but not at ſo great a diſtance. Smoke from dry roſin dropt on hot iron, does not deſtroy the repellency; but is attracted by both ſhot and cork-ball, forming proportionable atmoſpheres round them, making them look beautifully, ſomewhat like ſome of the figures in *Burnet*'s or *Whiſton*'s theory of the earth.

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* We ſuppoſe every particle of ſand, moiſture, or ſmoke, being firſt attracted and then repelled, carries off with it a portion of the electrical fire; but that the ſame ſtill ſubſiſts in thoſe particles, till they communicate it to ſomething elſe; and that it is never really deſtroyed.—So when water is thrown on common fire, we do not imagine the element is thereby deſtroyed or annihilated, but only diſperſed, each particle of water carrying off in vapour its portion of the fire, which it had attracted and attached to itſelf.

N. B. This

N. B. This experiment ſhould be made in a cloſet where the air is very ſtill.

The light of the ſun thrown ſtrongly on both cork and ſhot by a looking-glaſs for a long time together, does not impair the repellency in the leaſt. This difference between fire-light and ſun-light, is another thing that ſeems new and extraordinary to us.

We had for ſome time been of opinion, that the electrical fire was not created by friction, but collected, being really an element diffus'd among, and attracted by other matter, particularly by water and metals. We had even diſcovered and demonſtrated its afflux to the electrical ſphere, as well as its efflux, by means of little light windmill wheels made of ſtiff paper vanes, fixed obliquely and turning freely on fine wire axes. Alſo by little wheels of the ſame matter, but formed like water wheels. Of the diſpoſition and application of which wheels, and the various phænomena reſulting, I could, if I had time, fill you a ſheet. The impoſſibility of electriſing one's ſelf (tho' ſtanding on wax) by rubbing the tube and drawing the fire from it; and the manner of doing it by paſſing the tube near a perſon or thing ſtanding on the floor, &c. had alſo occurred to us ſome months before Mr *Watſon*'s ingenious *Sequel* came to hand, and theſe were ſome of the new things I intended to have communicated to you.—But now I need only mention ſome particulars not hinted in that piece, with our reaſonings thereupon; though perhaps the latter might well enough be ſpared.

1. A per-

1. A perſon ſtanding on wax, and rubbing the tube, and another perſon on wax drawing the fire; they will both of them, (provided they do not ſtand ſo as to touch one another) appear to be electriſed, to a perſon ſtanding on the floor; that is, he will perceive a ſpark on approaching each of them with his knuckle.

2. But if the perſons on wax touch one another during the exciting of the tube, neither of them will appear to be electriſed.

3. If they touch one another after exciting the tube, and drawing the fire as aforeſaid, there will be a ſtronger ſpark between them, than was between either of them and the perſon on the floor.

4. After ſuch ſtrong ſpark, neither of them diſcover any electricity.

Theſe appearances we attempt to account for thus. We ſuppoſe, as aforeſaid, that electrical fire is a common element, of which every one of the three perſons abovementioned has his equal ſhare, before any operation is begun with the tube. *A*, who ſtands on wax and rubs the tube, collects the electrical fire from himſelf into the glaſs; and his communication with the common ſtock being cut off by the wax, his body is not again immediately ſupply'd. *B*, (who ſtands on wax likewiſe) paſſing his knuckle along near the tube, receives the fire which was collected by the glaſs from *A*; and his communication with the common ſtock being likewiſe cut off, he retains the additional quantity received.—To *C*, ſtanding on the floor, both appear to be electriſed: for he having only the middle quantity of electrical fire, receives a ſpark upon approaching *B*, who has an over quantity; but gives one to *A*, who has an under quantity. If *A* and *B* approach to touch each other, the ſpark is ſtronger, becauſe the difference between them is greater; after ſuch touch there is no ſpark between either of them and *C*, becauſe the electrical fire in all is reduced to the original equality. If they touch while electriſing, the equality is never deſtroy'd, the fire only circulating. Hence have ariſen ſome new terms among us: we ſay, *B*, (and bodies like circumſtanced) is electriſed *poſitively*; *A*, *negatively*. Or rather, *B* is electriſed *plus*; *A*, *minus*. And we daily in our experiments electriſe bodies *plus* or *minus* as we think proper.—To electriſe *plus* or *minus*, no more needs to be known than this, that the parts of the tube or ſphere that are rubbed, do, in the inſtant of the friction attract the electrical fire, and therefore take it from the thing rubbing: the ſame parts immediately, as the friction upon them ceaſes, are diſpoſed to give the fire they have received, to any body that has leſs. Thus you may circulate it, as Mr *Watſon* has ſhewn; you may alſo accumulate or ſubſtract it upon or from any body, as you connect that body with the rubber or with the receiver, the communication with the common ſtock being cut off. We think that ingenious gentleman was deceived, when he imagined (in his *Sequel)* that the electrical fire came down the wire from the cieling to the gun-barrel, thence to the ſphere, and ſo electriſed the machine and the man turning the wheel, *&c.* We ſuppoſe it was *driven off*, and not brought on through that wire; and that the machine and man, *&c.* were electriſed *minus*; *i. e.* had leſs electrical fire in them than things in common.

As the veſſel is juſt upon ſailing, I cannot give you ſo large an account of *American* Electricity as I intended: I ſhall only mention a few particulars more,——We find granulated lead better to fill the phial with, than water, being eaſily warmed, and keeping warm and dry in damp air.—We fire ſpirits with the wire of the phial.——We light candles, juſt blown out, by drawing a ſpark among the ſmoke between the wire and ſnuffers.—We repreſent lightning, by paſſing the wire in the dark over a china plate that has gilt flowers, or applying it to gilt frames of looking-glaſſes, &c.—We electriſe a perſon twenty or more times running, with a touch of the finger on the wire, thus: He ſtands on wax. Give him the electriſed bottle in his hand. Touch the wire with your finger, and then touch his hand or face; there are ſparks every time.—We increaſe the force of the electrical kiſs vaſtly, thus: Let *A* and *B* ſtand on wax; give one of them the electriſed phial in hand; let the other take hold of the wire; there will be a ſmall ſpark; but when their lips approach, they will be ſtruck and ſhock'd. The ſame if another gentleman and lady, *C* and *D*, ſtanding alſo on wax, and joining hands with *A* and *B*, ſalute, or ſhake hands.—We ſuſpend by fine ſilk thread a counterfeit ſpider, made of a ſmall piece of burnt cork, with legs of linnen thread, and a grain or two of lead ſtuck in him to give him more weight. Upon the table, over which he hangs, we ſtick a wire upright as high as the phial and wire, two or three inches from the ſpider; then we animate him by ſetting the electrified phial at the ſame diſtance on the other ſide of him; he will immediately fly to the wire of the phial, bend his legs in touching it, then ſpring off; and fly to the wire in the table; thence again to the wire of the phial, playing with his legs againſt both in a very entertaining manner, appearing perfectly alive to perſons unacquainted. He will continue this motion an hour or more in dry weather.—We electrify, upon wax in the dark, a book that has a double line of gold round upon the covers, and then apply a knuckle to the gilding; the fire appears every where upon the gold like a flaſh of lightning: not upon the leather, nor, if you touch the leather inſtead of the gold. We rub our tubes with buckſkin, and obſerve always to keep the ſame ſide to the tube, and never to ſully the tube by handling; thus they work readily and eaſily, without the leaſt fatigue; eſpecially if kept in tight paſtboard caſes, lined with flannel, and fitting cloſe to the tube.*—This I mention becauſe the *European* papers, on Electricity, frequently ſpeak of rubbing the tube, as a fatiguing exerciſe. Our ſpheres are fixed on iron axes, which paſs through them. At one end of the axis there is a ſmall handle, with which you turn the ſphere like a common grindſtone. This we find very commodious, as the machine takes up but little room, is portable, and may be encloſed in a tight box, when not in uſe. 'Tis true, the ſphere does not turn ſo ſwift, as when the great wheel is uſed: but ſwiftneſs we think of little importance, ſince a few turns will charge the phial, *&c.* ſufficiently.

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* Our tubes are made here of green glaſs, 27 or 30 inches long, as big as can be graſped. Electricity is ſo much in vogue, that above one hundred of them have been ſold within theſe four months paſt.

I am, &c.

B. FRANKLIN.

LETTER III.

FROM

Mr BENJ. FRANKLIN, in *Philadelphia*,

TO

PETER COLLINSON, Eſq; F. R. S. *London.*

Farther EXPERIMENTS *and* OBSERVATIONS *in* ELECTRICITY.

SIR, 1748.

§ 1. THERE will be the ſame exploſion and ſhock if the electrified phial is held in one hand by the hook, and the coating touch'd with the other, as when held by the coating, and touch'd at the hook.

2. To take the charg'd phial ſafely by the hook, and not at the ſame time diminiſh its force, it muſt firſt be ſet down on an electric *per ſe*.

3. The phial will be electrified as ſtrongly, if held by the hook, and the coating apply'd to the globe or tube; as when held by the coating, and the hook apply'd.

4. But the *direction* of the electrical fire being different in the charging, will alſo be different in the exploſion. The bottle charged thro' the hook, will be diſcharged thro' the hook; the bottle charged thro' the coating, will be diſcharged thro' the coating, and not otherways: for the fire muſt come out the ſame way it went in.

5. To prove this; take two bottles that were equally charged thro' the hooks, one in each hand; bring their hooks near each other, and no ſpark or ſhock will follow; becauſe each hook is diſpoſed to give fire, and neither to receive it. Set one of the bottles down on glaſs, take it up by the hook, and apply its coating to the hook of the other; then there will be an exploſion and ſhock, and both bottles will be diſcharged.

6. Vary the experiment, by charging two phials equally, one thro' the hook, the other thro' the coating: hold that by the coating which was charged thro' the hook; and that by the hook which was charged thro' the coating: apply the hook of the firſt to the coating of the other, and there will be no ſhock or ſpark. Set that down on glaſs which you held by the hook, take it up by the coating, and bring the two hooks together: a ſpark and ſhock will follow, and both phials be diſcharged.

In this experiment the bottles are totally diſcharged, or the equilibrium within them reſtored. The *abounding* of fire in one of the hooks (or rather in the internal ſurface of one bottle) being exactly equal to the *wanting* of the other: and therefore, as each bottle has in itſelf the *abounding* as well as the *wanting*, the wanting and abounding muſt be equal in each bottle. See §. 8, 9, 10, 11. But if a man holds in his hands two bottles, one fully electrify'd, the other not at all, and brings their hooks together, he has but half a ſhock, and the bottles will both remain half electrified, the one being half diſcharged, and the other half charged.

7. Place two phials equally charged on a table at five or ſix inches diſtance. Let a cork-ball, ſuſpended by a ſilk thread, hang between them. If the phials were both charged through their hooks, the cork, when it has been attracted and repell'd by the one, will not be attracted, but equally repelled by the other. But if the phials were charged, the one thro' the hook, and the other * thro' the coating, the ball, when it is repelled from one hook, will be as ſtrongly attracted by the other, and play vigorouſly between them, 'till both phials are nearly diſcharged.

8. When we uſe the terms of *charging* and *diſcharging* the phial, 'tis in compliance with cuſtom, and for want of others more ſuitable. Since we are of opinion, that there is really no more electrical fire in the phial after what is called its *charging*, than before, nor leſs after its *diſcharging*; excepting only the ſmall ſpark that might be given to, and taken from, the non-electric matter, if ſeparated from

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* To charge a bottle commodiouſly through the coating, place it on a glaſs ſtand; form a communication from the prime conductor to the coating, and another from the hook to the wall or floor. When it is charged, remove the latter communication before you take hold of the bottle, otherwiſe great part of the fire will eſcape by it.

the bottle, which ſpark may not be equal to a five hundredth part of what is called the exploſion.

For if, on the exploſion, the electrical fire came out of the bottle by one part, and did not enter in again by another; then, if a man ſtanding on wax, and holding the bottle in one hand, takes the ſpark by touching the wire hook with the other, the bottle being thereby *diſcharged*, the man would be *charged*; or whatever fire was loſt by one, would be found in the other, ſince there was no way for its eſcape: But the contrary is true.

9. Beſides, the phial will not ſuffer what is called a *charging*, unleſs as much fire can go out of it one way, as is thrown in by another. A phial cannot be charged ſtanding on wax or glaſs, or hanging on the prime conductor, unleſs a communication be formed between its coating and the floor.

10. But ſuſpend two or more phials on the prime conductor, one hanging to the tail of the other; and a wire from the laſt to the floor, an equal number of turns of the wheel ſhall charge them all equally, and every one as much as one alone would have been. What is driven out at the tail of the firſt, ſerving to charge the ſecond; what is driven out of the ſecond charging the third; and ſo on. By this means a great number of bottles might be charged with the ſame labour, and equally high, with one alone, were it not that every bottle receives new fire, and loſes its old with ſome reluctance, or rather gives ſome ſmall reſiſtance to the charging, which in a number of bottles becomes

comes more equal to the charging power, and ſo repels the fire back again on the globe, ſooner than a ſingle bottle would do.

11. When a bottle is charged in the common way, its *inſide* and *outſide* ſurfaces ſtand ready, the one to give fire by the hook, the other to receive it by the coating; the one is full, and ready to throw out, the other empty and extremely hungry; yet as the firſt will not *give out*, unleſs the other can at the ſame inſtant *receive in*; ſo neither will the latter receive in, unleſs the firſt can at the ſame inſtant give out. When both can be done at once, 'tis done with inconceivable quickneſs and violence.

12. So a ſtrait ſpring (tho' the compariſon does not agree in every particular) when forcibly bent, muſt, to reſtore itſelf, contract that ſide which in the bending was extended, and extend that which was contracted; if either of theſe two operations be hindered, the other cannot be done. But the ſpring is not ſaid to be *charg'*d with elaſticity when bent, and diſcharg'd when unbent; its quantity of elaſticity is always the ſame.

13. Glaſs, in like manner, has, within its ſubſtance, always the ſame quantity of electrical fire, and that a very great quantity in proportion to the maſs of glaſs, as ſhall be ſhewn hereafter.

14. This quantity, proportioned to the glaſs, it ſtrongly and obſtinately retains, and will have neither more nor leſs, though it will ſuffer a change to be made in its parts and ſituation; *i. e.* we may take away part of it from one

of the ſides, provided we throw an equal quantity into the other.

15. Yet when the ſituation of the electrical fire is thus altered in the glaſs; when ſome has been taken from one ſide, and ſome added to the other, it will not be at reſt or in its natural ſtate, till 'tis reſtored to its original equality.—And this reſtitution cannot be made through the ſubſtance of the glaſs, but muſt be done by a non-electric communication formed without, from ſurface to ſurface.

16. Thus, the whole force of the bottle, and power of giving a ſhock, is in the GLASS ITSELF; the non-electrics in contact with the two ſurfaces, ſerving only to *give* and *receive* to and from the ſeveral parts of the glaſs; that is, to give on one ſide, and take away from the other.

17. This was diſcovered here in the following manner: Purpoſing to analyſe the electrified bottle, in order to find wherein its ſtrength lay, we placed it on glaſs, and drew out the cork and wire which for that purpoſe had been looſely put in. Then taking the bottle in one hand, and bringing a finger of the other near its mouth, a ſtrong ſpark came from the water, and the ſhock was as violent as if the wire had remained in it, which ſhewed that the force did not lie in the wire. Then to find if it reſided in the water, being crouded into and condenſed in it, as confin'd by the glaſs, which had been our former opinion, we electrify'd the bottle again, and placing it on glaſs, drew out the wire and cork as before; then taking up the bottle, we decanted all its water into an empty bottle, which likewiſe ſtood on

glaſs; and taking up that other bottle, we expected if the force reſided in the water, to find a ſhock from it; but there was none. We judged then, that it muſt either be loſt in decanting, or remain in the firſt bottle. The latter we found to be true: for that bottle on trial gave the ſhock, though filled up as it ſtood with freſh unelectrified water from a tea-pot.—To find then, whether glaſs had this property merely as glaſs, or whether the form contributed any thing to it; we took a pane of ſaſh-glaſs, and laying it on the ſtand, placed a plate of lead on its upper ſurface; then electrify'd that plate, and bringing a finger to it, there was a ſpark and ſhock. We then took two plates of lead of equal dimenſions, but leſs than the glaſs by two inches every way, and electrified the glaſs between them, by electrifying the uppermoſt lead; then ſeparated the glaſs from the lead, in doing which, what little fire might be in the lead was taken out, and the glaſs being touched in the electrified parts with a finger, afforded only very ſmall pricking ſparks, but a great number of them might be taken from different places. Then dexterouſly placing it again between the leaden plates, and compleating a circle between the two ſurfaces, a violent ſhock enſued.——Which demonſtrated the power to reſide in glaſs as glaſs, and that the non-electrics in contact ſerved only, like the armature of a loadſtone, to unite the force of the ſeveral parts, and bring them at once to any point deſired: it being a property of a non-electric, that the whole body inſtantly receives or gives what electrical fire is given to or taken from any one of its parts.

18. Upon this, we made what we call'd an *electrical-battery*, conſiſting of eleven panes of large ſaſh-glaſs, arm'd with thin leaden plates paſted on each ſide, placed vertically, and ſupported at two inches diſtance on ſilk cords, with thick hooks of leaden wire, one from each ſide, ſtanding upright, diſtant from each other, and convenient communications of wire and chain, from the giving ſide of one pane, to the receiving ſide of the other; that ſo the whole might be charged together, and with the ſame labour as one ſingle pane; and another contrivance to bring the giving ſides, after charging, in contract with one long wire, and the receivers with another, which two long wires would give the force of all the plates of glaſs at once through the body of any animal forming the circle with them. The plates may alſo be diſcharged ſeparately, or any number together that is required. But this machine is not much uſed, as not perfectly anſwering our intention with regard to the eaſe of charging, for the reaſon given §. 10. We made alſo of large glaſs panes, magical pictures, and ſelf-moving animated wheels, preſently to be deſcribed.

19. I perceive by the ingenious Mr *Watſon*'s laſt book, lately received, that Dr *Bevis* had uſed, before we had, panes of glaſs to give a ſhock; though, till that book came to hand, I thought to have communicated it to you as a novelty. The excuſe for mentioning it here is, that we

tried the experiment differently, drew different conſequences from it, (for Mr *Watſon* ſtill ſeems to think the fire *accumulated on the non-electric* that is in contact with the glaſs, page 72) and, as far as we hitherto know, have carried it farther.

20. The magical picture is made thus. Having a large metzotinto with a frame and glaſs, ſuppoſe of the KING, (God preſerve him) take out the print, and cut a pannel out of it, near two inches diſtant from the frame all round. If the cut is through the picture 'tis not the worſe. With thin paſte, or gum-water, fix the border that is cut off on the inſide of the glaſs, preſſing it ſmooth and cloſe; then fill up the vacancy by gilding the glaſs well with leaf gold or braſs. Gild likewiſe the inner edge of the back of the frame all round except the top part, and form a communication between that gilding and the gilding behind the glaſs: then put in the board, and that ſide is finiſhed. Turn up the glaſs, and gild the fore ſide exactly over the back gilding, and when it is dry, cover it by paſting on the pannel of the picture that hath been cut out, obſerving to bring the correſpondent parts of the border and picture together, by which the picture will appear of a piece as at firſt, only part is behind the glaſs, and part before.—Hold the picture horizontally by the top, and place a little moveable gilt crown on the king's head. If now the picture be moderately electrified, and another perſon take hold of the frame with one hand, ſo that his fingers touch its inſide gilding, and with the other hand endeavour to take

off the crown, he will receive a terrible blow, and fail in the attempt. If the picture were highly charged, the conſequence might perhaps be as fatal as that of high-treaſon; for when the ſpark is taken through a quire of paper laid on the picture, by means of a wire communication, it makes a fair hole thro' every ſheet, that is, thro' 48 leaves, (though a quire of paper is thought good armour againſt the puſh of a ſword, or even againſt a piſtol bullet) and the crack is exceeding loud. The operator, who holds the picture by the upper end, where the inſide of the frame is not gilt, to prevent its falling, feels nothing of the ſhock, and may touch the face of the picture without danger, which he pretends is a teſt of his loyalty.——If a ring of perſons take the ſhock among them, the experiment is called, *The Conſpirators.*

21. On the principle, in §. 7, that hooks of bottles, differently charged, will attract and repel differently, is made an electrical wheel, that turns with conſiderable ſtrength. A ſmall upright ſhaft of wood paſſes at right angles through a thin round board, of about twelve inches diameter, and turns on a ſharp point of iron fixed in the lower end, while a ſtrong wire in the upper end paſſing thro' a ſmall hole in a thin braſs plate, keeps the ſhaft truly vertical. About thirty *radii* of equal length, made of ſaſh-glaſs cut in narrow ſtrips, iſſue horizontally from the circumference of the board, the ends moſt diſtant from the center being about four inches apart. On the end of every one, a braſs thimble is fixed. If now the wire of a bottle electrified in the

common way, be brought near the circumference of this wheel, it will attract the neareſt thimble, and ſo put the wheel in motion; that thimble, in paſſing by, receives a ſpark, and thereby being electrified is repelled, and ſo driven forwards; while a ſecond being attracted, approaches the wire, receives a ſpark, and is driven after the firſt, and ſo on till the wheel has gone once round, when the thimbles before electrified approaching the wire, inſtead of being attracted as they were at firſt, are repelled, and the motion preſently ceaſes.—But if another bottle which had been charged through the coating be placed near the ſame wheel, its wire will attract the thimble repelled by the firſt, and thereby double the force that carries the wheel round; and not only taking out the fire that had been communicated to the thimbles by the firſt bottle, but even robbing them of their natural quantity, inſtead of being repelled when they come again towards the firſt bottle, they are more ſtrongly attracted, ſo that the wheel mends its pace, till it goes with great rapidity twelve or fifteen rounds in a minute, and with ſuch ſtrength, as that the weight of one hundred *Spaniſh* dollars with which we once loaded it, did not ſeem in the leaſt to retard its motion.—This is called an electrical jack; and if a large fowl were ſpitted on the upright ſhaft, it would be carried round before a fire with a motion fit for roaſting.

22. But this wheel, like thoſe driven by wind, water, or weights, moves by a foreign force, to wit, that of the bottles. The ſelf-moving wheel, though conſtructed on the

ſame principles, appears more ſurpriſing. 'Tis made of a thin round plate of window-glaſs, ſeventeen inches diameter, well gilt on both ſides, all but two inches next the edge. Two ſmall hemiſpheres of wood are then fixed with cement to the middle of the upper and under ſides, centrally oppoſite, and in each of them a thick ſtrong wire eight or ten inches long, which together make the axis of the wheel. It turns horizontally on a point at the lower end of its axis, which reſts on a bit of braſs cemented within a glaſs ſalt-cellar. The upper end of its axis paſſes thro' a hole in a thin braſs plate cemented to a long ſtrong piece of glaſs, which keeps it ſix or eight inches diſtant from any non-electric, and has a ſmall ball of wax or metal on its top to keep in the fire. In a circle on the table which ſupports the wheel, are fixed twelve ſmall pillars of glaſs, at about four inches diſtance, with a thimble on the top of each. On the edge of the wheel is a ſmall leaden bullet, communicating by a wire with the gilding of the *upper* ſurface of the wheel; and about ſix inches from it is another bullet communicating in like manner with the *under* ſurface. When the wheel is to be charged by the upper ſurface, a communication muſt be made from the under ſurface to the table. When it is well charged it begins to move; the bullet neareſt to a pillar moves towards the thimble on that pillar, and paſſing by electrifies it, and then puſhes itſelf from it; the ſucceeding bullet, which communicates with the other ſurface of the glaſs, more ſtrongly attracts that thimble on account of its being before ſore electrified by the other bullet; and thus the wheel encreaſes its motion till it comes to ſuch a height as that the reſiſtance of the air regulates it. It will go half an hour, and make one minute with another twenty turns in a minute, which is ſix hundred turns in the whole; the bullet of the upper ſurface giving in each turn twelve ſparks, to the thimbles, which makes ſeven thouſand two hundred ſparks; and the bullet of the under ſurface receiving as many from the thimbles; thoſe bullets moving in the time near two thouſand five hundred feet.—The thimbles are well fixed, and in ſo exact a circle, that the bullets may paſs within a very ſmall diſtance of each of them.—If inſtead of two bullets you put eight, four communicating with the upper ſurface, and four with the under ſurface, placed alternately; which eight, at about ſix inches diſtance, completes the circumference, the force and ſwiftneſs will be greatly increaſed, the wheel making fifty turns in a minute; but then it will not continue moving ſo long.——Theſe wheels may be applied, perhaps, to the ringing of chimes, and moving of light-made Orreries.

23. A ſmall wire bent circularly with a loop at each end; let one end reſt againſt the under ſurface of the wheel, and bring the other end nearer the upper ſurface, it will give a terrible crack, and the force will be diſcharged.

24. Every ſpark in that manner drawn from the ſurface of the wheel, makes a round hole in the gilding, tearing off a part of it in coming out; which ſhews that the fire

is not accumulated on the gilding, but is in the glaſs itſelf.

25. The gilding being varniſhed over with turpentine varniſh, the varniſh, tho' dry and hard, is burnt by the ſpark drawn thro' it, and gives a ſtrong ſmell and viſible ſmoke. And when the ſpark is drawn thro' paper, all round the hole made by it, the paper will be blacked by the ſmoke, which ſometimes penetrates ſeveral of the leaves. Part of the gilding torn off, is alſo found forcibly driven into the hole made in the paper by the ſtroke.

26. 'Tis amazing to obſerve in how ſmall a portion of glaſs a great electrical force may lie. A thin glaſs bubble, about an inch diameter, weighing only ſix grains, being half filled with water, partly gilt on the outſide, and furniſh'd with a wire hook, gives, when electrified, as great a ſhock as a man can well bear. As the glaſs is thickeſt near the orifice, I ſuppoſe the lower half, which being gilt was electrified, and gave the ſhock, did not exceed two grains; for it appeared, when broke, much thinner than the upper half.—If one of theſe thin bottles be electrified by the coating, and the ſpark taken out thro' the gilding, it will break the glaſs inwards at the ſame time that it breaks the gilding outwards.

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27. And allowing (for the reaſons before given, §. 8, 9, 10.) that there is no more electrical fire in a bottle after charging, than before, how great muſt be the quantity in this ſmall portion of glaſs! It ſeems as if it were of its very ſubſtance and eſſence. Perhaps if that due quantity of

electrical fire ſo obſtinately retained by glaſs, could be ſeparated from it, it would no longer be glaſs; it might loſe its tranſparency, or its brittleneſs, or its elaſticity.—Experiments may poſſibly be invented hereafter, to diſcover this.

27. We were ſurpriſed at the account given in Mr *Watſon*'s book, of a ſhock communicated through a great ſpace of dry ground, and ſuſpect there muſt be ſome metaline quality in the gravel of that ground; having found that ſimple dry earth, rammed in a glaſs tube, open at both ends, and a wire hook inſerted in the earth at each end, the earth and wires making part of a circle, would not conduct the leaſt perceptible ſhock, and indeed when one wire was electrify'd, the other hardly ſhowed any ſigns of its being in connection with it.—Even a thoroughly wet pack-thread ſometimes fails of conducting a ſhock, tho' it otherwiſe conducts electricity very well. A dry cake of ice, or an icicle held between two in a circle, likewiſe prevents the ſhock; which one would not expect, as water conducts it ſo perfectly well.—Gilding on a new book, tho' at firſt it conducts the ſhock extremely well, yet fails after ten or a dozen experiments, though it appears otherwiſe in all reſpects the ſame, which we cannot account for.

28. There is one experiment more which ſurprizes us, and is not hitherto ſatisfactorily accounted for; it is this: Place an iron ſhot on a glaſs ſtand, and let a ball of damp cork, ſuſpended by a ſilk thread, hang in contact with the

ſhot. Take a bottle in each hand, one that is electrify'd through the hook, the other through the coating: Apply the giving wire to the ſhot, which will electrify it *poſitively*, and the cork ſhall be repelled: then apply the requiring wire, which will take out the ſpark given by the other; when the cork will return to the ſhot: Apply the ſame again, and take out another ſpark, ſo will the ſhot be electrify'd *negatively*; and the cork in that caſe ſhall be repelled equally as before. Then apply the giving wire to the ſhot, and give the ſpark it wanted, ſo will the cork return: Give it another, which will be an addition to its natural quantity, ſo will the cork be repelled again: And ſo may the experiment be repeated as long as there is any charge in the bottles. Which ſhews that bodies having leſs than the common quantity of Electricity, repel each other, as well as thoſe that have more.

Chagrined a little that we have hitherto been able to produce nothing in this way of uſe to mankind; and the hot weather coming on, when electrical experiments are not ſo agreeable, 'tis propoſed to put an end to them for this ſeaſon, ſomewhat humorouſly, in a party of pleaſure, on the banks of *Skuylkil* *. Spirits, at the ſame time, are to be fired by a ſpark ſent from ſide to ſide through the river, without any other conductor than the water; an experiment which we ſome time ſince performed, to the

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[*] The river that waſhes one ſide of *Philadelphia*, as the *Delaware* does the other; both are ornamented with the ſummer habitations of the citizens, and the agreeable manſions of the principle people of this colony.

amazement of many. A turkey is to be killed for our dinner by the *electrical ſhock*, and roaſted by the *electrical jack*, before a fire kindled by the *electrified bottle*; when the healths of all the famous electricians in *England*, *Holland*, *France*, and *Germany*, are to be drank in * *electrified bumpers*, under the diſcharge of guns from the *electrical battery*.

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* An *electrified bumper* is a ſmall thin glaſs tumbler, near filled with wine, and electrified as the bottle. This when brought to the lips gives a ſhock, if the party be cloſe ſhaved, and does not breathe on the liquor.

April 29,
1749.

LETTER IV.

CONTAINING

OBSERVATIONS *and* SUPPOSITIONS, *towards forming a new* HYPOTHESIS, *for explaining the ſeveral* Phænomena *of* THUNDER GUSTS*.

SIR,

§. 1. NON-ELECTRIC bodies, that have electric fire thrown into them, will retain it till other non-electrics, that have leſs, approach; and then 'tis communicated by a ſnap, and becomes equally divided.

2. Electrical fire loves water, is ſtrongly attracted by it, and they can ſubſiſt together.

3. Air is an electric *per ſe*, and when dry will not conduct the electrical fire; it will neither receive it, nor give

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* Thunder-guſts are ſudden ſtorms of thunder and lightning, which are frequently of ſhort duration, but ſometimes produce miſchievous effects.

it to other bodies; otherwiſe no body ſurrounded by air could be electrified poſitively and negatively: for ſhould it be attempted poſitively, the air would immediately take away the overplus; or negatively, the air would ſupply what was wanting.

4. Water being electrified, the vapours ariſing from it will be equally electrified; and floating in the air, in the form of clouds, or otherwiſe, will retain that quantity of electrical fire, till they meet with other clouds or bodies not ſo much electrified, and then will communicate as before mentioned.

5. Every particle of matter electrified is repelled by every other particle equally electrified. Thus the ſtream of a fountain, naturally denſe and continual, when electrified, will ſeparate and ſpread in the form of a bruſh, every drop endeavouring to recede from every other drop. But on taking out the electrical fire, they cloſe again.

6. Water being ſtrongly electrified (as well as when heated by common fire) riſes in vapours more copiouſly; the attraction of coheſion among its particles being greatly weakened, by the oppoſite power of repulſion introduced with the electrical fire; and when any particle is by any means diſengaged, 'tis immediately repelled, and ſo flies into the air.

7. Particles happening to be ſituated as *A* and *B*, are more eaſily diſengaged than *C* and *D*, as each is held by contact with three only, whereas *C* and *D* are each in contact with nine. When the ſurface of water has the

leaſt motion, particles are continually puſhed into the ſituation repreſented by *A* and *B*, FIG. 6.

8. Friction between a non-electric and an electric *per ſe* will produce electrical fire; not by *creating*, but *collecting* it: for it is equally diffuſed in our walls, floors, earth, and the whole maſs of common matter. Thus the whirling glaſs globe, during its friction againſt the cuſhion, draws fire from the cuſhion, the cuſhion is ſupplied from the frame of the machine, that from the floor on which it ſtands. Cut off the communication by thick glaſs or wax placed under the cuſhion, and no fire can be *produced*, becauſe it cannot be *collected*.

9. The Ocean is a compound of water, a non-electric, and ſalt an electric *per ſe*.

10. When there is a friction among the parts near its ſurface, the electrical fire is collected from the parts below. It is then plainly viſible in the night; it appears at the ſtern and in the wake of every ſailing veſſel; every daſh of an oar ſhows it, and every ſurff and ſpray: in ſtorms the whole ſea ſeems on fire.—The detach'd particles of water then repelled from the electrified ſurface, continually carry off the fire as it is collected; they riſe, and form clouds, and thoſe clouds are highly electrified, and retain the fire till they have an opportunity of communicating it.

11. The particles of water riſing in vapours, attach themſelves to particles of air.

12. The particles of air are ſaid to be hard, round, ſeparate and diſtant from each other; every particle ſtrongly

repelling every other particle, whereby they recede from each other, as far as common gravity will permit.

13. The ſpace between any three particles equally repelling each other, will be an equilateral triangle.

14. In air compreſſed, theſe triangles are ſmaller; in rarified air they are larger.

15. Common fire joined with air, increaſes the repulſion, enlarges the triangles, and thereby makes the air ſpecifically lighter. Such air, among denſer air, will riſe.

16. Common fire, as well as electrical fire, gives repulſion to the particles of water, and deſtroys their attraction of coheſion; hence common fire, as well as electrical fire, aſſiſts in raiſing vapours.

17. Particles of water, having no fire in them, mutually attract each other. Three particles of water then being attached to the three particles of a triangle of air, would by their mutual attraction operating againſt the air's repulſion, ſhorten the ſides and leſſen the triangle, whereby that portion of air being made denſer, would ſink to the earth with its water, and not riſe to contribute to the formation of a cloud.

18. But if every particle of water attaching itſelf to air, brings with it a particle of common fire, the repulſion of the air being aſſiſted and ſtrengthened by the fire, more than obſtructed by the mutual attraction of the particles of water, the triangle dilates, and that portion of air becoming rarer and ſpecifically lighter riſes.

19. If the particles of water bring electrical fire when

they attach themſelves to air, the repulſion between the particles of water electrified, joins with the natural repulſion of the air, to force its particles to a greater diſtance, whereby the triangles are dilated, and the air riſes, carrying up with it the water.

20. If the particles of water bring with them portions of *both ſorts* of fire, the repulſion of the particles of air is ſtill more ſtrengthened and increaſed, and the triangles farther enlarged.

21. One particle of air may be ſurrounded by twelve particles of water of equal ſize with itſelf, all in contact with it; and by more added to thoſe.

22. Particles of air thus loaded would be drawn nearer together by the mutual attraction of the particles of water, did not the fire, common or electrical, aſſiſt their repulſion.

23. If air thus loaded be compreſſed by adverſe winds, or by being driven againſt mountains, *&c.* or condenſed by taking away the fire that aſſiſted it in expanding; the triangles contract, the air with its water will deſcend as a dew; or, if the water ſurrounding one particle of air comes in contact with the water ſurrounding another, they coaleſce and form a drop, and we have rain.

24. The ſun ſupplies (or ſeems to ſupply) common fire to all vapours, whether raiſed from earth or ſea.

25. Thoſe vapours which have both common and electrical fire in them, are better ſupported, than thoſe which have only common fire in them. For when vapours riſe

into the coldeſt region above the earth, the cold will not diminiſh the electrical fire, if it doth the common.

26. Hence clouds formed by vapours raiſed from freſh waters within land, from growing vegetables, moiſt earth, *&c.* more ſpeedily and eaſily depoſite their water, having but little electrical fire to repel and keep the particles ſeparate. So that the greateſt part of the water raiſed from the land is let fall on the land again; and winds blowing from the land to the ſea are dry; there being little uſe for rain on the ſea, and to rob the land of its moiſture, in order to rain on the ſea, would not appear reaſonable.

27. But clouds formed by vapours raiſed from the ſea, having both fires, and particularly a great quantity of the electrical, ſupport their water ſtrongly, raiſe it high, and being moved by winds, may bring it over the middle of the broadeſt continent from the middle of the wideſt ocean.

28. How theſe ocean clouds, ſo ſtrongly ſupporting their water, are made to depoſite it on the land where 'tis wanted, is next to be conſidered.

29. If they are driven by winds againſt mountains, thoſe mountains being leſs electrified attract them, and on contact take away their electrical fire (and being cold, the common fire alſo;) hence the particles cloſe towards the mountains and towards each other. If the air was not much loaded, it only falls in dews on the mountain tops and ſides, forms ſprings, and deſcends to the vales in rivulets, which united make larger ſtreams and rivers. If much loaded, the electrical fire is at once taken from the

whole cloud; and, in leaving it, flaſhes brightly and cracks loudly; the particles inſtantly coaleſcing for want of that fire, and falling in a heavy ſhower.

30. When a ridge of mountains thus dams the clouds, and draws the electrical fire from the cloud firſt approaching it; that which next follows, when it comes near the firſt cloud, now deprived of its fire, flaſhes into it, and begins to depoſite its own water; the firſt cloud again flaſhing into the mountains; the third approaching cloud, and all the ſucceeding ones, acting in the ſame manner as far back as they extend, which may be over many hundred miles of country.

31. Hence the continual ſtorms of rain, thunder, and lightning on the eaſt-ſide of the *Andes*, which running north and ſouth, and being vaſtly high, intercept all the clouds brought againſt them from the *Atlantic* ocean by the trade winds, and oblige them to depoſite their waters, by which the vaſt rivers *Amazons*, *La Plata*, and *Oroonoko* are formed, which return the water into the ſame ſea, after having fertilized a country of very great extent.

32. If a country be plain, having no mountains to intercept the electrified clouds, yet it is not without means to make them depoſite their water. For if an electrified cloud coming from the ſea, meets in the air a cloud raiſed from the land, and therefore not electrified; the firſt will flaſh its fire into the latter, and thereby both clouds ſhall be made ſuddenly to depoſite water.

33. The electrified particles of the firſt cloud cloſe when they loſe their fire; the particles of the other cloud

cloſe in receiving it: in both, they have thereby an opportunity of coaleſcing into drops.—The concuſſion or jerk given to the air, contributes alſo to ſhake down the water, not only from thoſe two clouds but from others near them. Hence the ſudden fall of rain immediately after flaſhes of lightning.

34. To ſhew this by an eaſy experiment: Take two round pieces of paſteboard two inches diameter; from the center and circumference of each of them ſuſpend by fine ſilk threads eighteen inches long, ſeven ſmall balls of wood, or ſeven peas equal in bigneſs; ſo will the balls appending to each paſteboard, form equal equilateral triangles, one ball being in the center, and ſix at equal diſtances from that, and from each other; and thus they repreſent particles of air. Dip both ſets in water, and ſome cohering to each ball, they will repreſent air loaded. Dexterouſly electrify'd one ſet, and its balls will repel each other to a greater diſtance, enlarging the triangles. Could the water ſupported by the ſeven balls come into contact, it would form a drop or drops ſo heavy as to break the coheſion it had with the balls, and ſo fall. Let the two ſets then repreſent two clouds, the one a ſea cloud electrified, the other a land cloud. Bring them within the ſphere of attraction, and they will draw towards each other, and you will ſee the ſeparated balls cloſe thus; the firſt electrified ball that comes near an unelectrified ball by attraction joins it, and gives it fire; inſtantly they ſeparate, and each flies to another ball of its own party, one to

give, the other to receive fire; and ſo it proceeds through both ſets, but ſo quick as to be in a manner inſtantaneous. In the colliſion they ſhake off and drop their water, which repreſents rain.

35. Thus when ſea and land clouds would paſs at too great a diſtance from the flaſh, they are attracted towards each other till within that diſtance; for the ſphere of electrical attraction is far beyond the diſtance of flaſhing.

36. When a great number of clouds from the ſea meet a number of clouds raiſed from the land, the electrical flaſhes appear to ſtrike in different parts; and as the clouds are joſtled and mixed by the winds, or brought near by the electrical attraction, they continue to give and receive flaſh after flaſh, till the electrical fire is equally diffuſed.

37. When the gun-barrel (in electrical experiments) has but little electrical fire in it, you muſt approach it very near with your knuckle, before you can draw a ſpark. Give it more fire, and it will give a ſpark at a greater diſtance. Two gun-barrels united, and as highly electrified, will give a ſpark at a ſtill greater diſtance. But if two gun-barrels electrified will ſtrike at two inches diſtance, and make a loud ſnap, to what a great diſtance may 10,000 acres of electrified cloud ſtrike and give its fire, and how loud muſt be that crack?

38. It is a common thing to ſee clouds at different heights paſſing different ways, which ſhews different currents of air, one under the other. As the air between the

tropics is rarified by the ſun, it raiſes, the denſer northern and ſouthern air preſſing into its place. The air ſo rarified and forced up, paſſes northward and ſouthward, and muſt deſcend in the polar regions, if it has no opportunity before, that the circulation may be carried on.

39. As currents of air, with the clouds therein, paſs different ways, 'tis eaſy to conceive how the clouds, paſſing over each other, may attract each other, and ſo come near enough for the electrical ſtroke. And alſo how electrical clouds may be carried within land very far from the ſea, before they have an opportnnity to ſtrike.

40. When the air, with its vapours raiſed from the ocean between the tropics, comes to deſcend in the polar regions, and to be in contact with the vapours ariſing there, the electrical fire they brought begins to be communicated, and is ſeen in clear nights, being firſt viſible where 'tis firſt in motion, that is, where the contact begins, or in the moſt northern part; from thence the ſtreams of light ſeem to ſhoot ſoutherly, even up to the zenith of northern countries. But tho' the light ſeems to ſhoot from the north ſoutherly, the progreſs of the fire is really from the ſouth northerly, its motion beginning in the north being the reaſon that 'tis there firſt ſeen.

For the electrical fire is never viſible but when in motion, and leaping from body to body, or from particle to particle thro' the air. When it paſſes thro' denſe bodies 'tis unſeen. When a wire makes part of the circle, in the exploſion of the electrical phial, the fire, though in great quantity, paſſes in the wire inviſibly: but in paſſing along a chain, it becomes viſible as it leaps from link to link. In paſſing along leaf gilding 'tis viſible: for the leaf-gold is full of pores; hold a leaf to the light and it appears like a net; and the fire is ſeen in its leaping over the vacancies.— And as when a long canal filled with ſtill water is opened at one end, in order to be diſcharged, the motion of the water begins firſt near the opened end, and proceeds towards the cloſe end, tho' the water itſelf moves from the cloſe towards the opened end: ſo the electrical fire diſcharged into the polar regions, perhaps from a thouſand leagues length of vaporiz'd air, appears firſt where 'tis firſt in motion, *i. e.* in the moſt northern part, and the appearance proceeds ſouthward, tho' the fire really moves northward. This is ſuppoſed to account for the *Aurora Borealis.*

41. When there is great heat on the land, in a particular region (the ſun having ſhone on it perhaps ſeveral days, while the ſurrounding countries have been ſcreen'd by clouds) the lower air is rarified and riſes, the cooler denſer air above deſcends; the clouds in that air meet from all ſides, and join over the heated place; and if ſome are electrified, others not, lightning and thunder ſucceed, and ſhowers fall. Hence thunder-guſts after heats, and cool air after guſts; the water and the clouds that bring it, coming from a higher and therefore a cooler region.

42. An electrical ſpark, drawn from an irregular body at ſome diſtance is ſcarce ever ſtrait, but ſhows crooked

and waving in the air. So do the flaſhes of lightning; the clouds being very irregular bodies.

43. As electrified clouds paſs over a country, high hills and high trees, lofty towers, ſpires, maſts of ſhips, chimneys, *&c.* as ſo many prominencies and points, draw the electrical fire, and the whole cloud diſcharges there.

44. Dangerous, therefore, is it to take ſhelter under a tree during a thunder-guſt. It has been fatal to many, both men and beaſts.

45. It is ſafer to be in the open field for another reaſon. When the cloaths are wet, if a flaſh in its way to the ground ſhould ſtrike your head, it will run in the water over the ſurface of your body; whereas, if your cloaths were dry, it would go through the body.

Hence a wet rat cannot be killed by the exploding electrical bottle, when a dry rat may.

46. Common fire is in all bodies, more or leſs, as well as electrical fire. Perhaps they may be different modifications of the ſame element; or they may be different elements. The latter is by ſome ſuſpected.

47. If they are different things, yet they may and do ſubſiſt together in the ſame body.

48. When electrical fire ſtrikes through a body, it acts upon the common fire contained in it, and puts that fire in motion; and if there be a ſufficient quantity of each kind of fire, the body will be inflamed.

49. When the quantity of common fire in the body is ſmall, the quantity of the electrical fire (or the electrical

ſtroke) ſhould be greater: if the quantity of common fire be great, leſs electrical fire ſuffices to produce the effect.

50. Thus ſpirits muſt be heated before we can fire them by the electrical ſpark. If they are much heated a ſmall ſpark will do; if not, the ſpark muſt be greater.

51. 'Till lately we could only fire warm vapours; but now we can burn hard dry roſin. And when we can procure greater electrical ſparks, we may be able to fire not only unwarm'd ſpirits, as lightning does, but even wood, by giving ſufficient agitation to the common fire contained in it, as friction we know will do.

52. Sulphureous and inflammable vapours ariſing from the earth, are eaſily kindled by lightning. Beſides what ariſe from the earth, ſuch vapours are ſent out by ſtacks of moiſt hay, corn, or other vegetables, which heat and reek. Wood rotting in old trees or buildings does the ſame. Such are therefore eaſily and often fired.

53. Metals are often melted by lightning, tho' perhaps not from heat in the lightning, not altogether from agitated fire in the metals.—For as whatever body can inſinuate itſelf between the particles of metal, and overcome the attraction by which they cohere (as ſundry menſtrua can) will make the ſolid become a fluid, as well as fire, yet without heating it: ſo the electrical fire, or lightning, creating a violent repulſion between the particles of the metal it paſſes thro', the metal is fuſed.

54. If you would, by a violent fire, melt off the end of a nail, which is half driven into a door, the heat given the

whole nail before a part would melt, muſt burn the board it ſticks in. And the melted part would burn the floor it dropp'd on. But if a ſword can be melted in the ſcabbard, and money in a man's pocket, by lightning, without burning either, it muſt be a cold fuſion.

55. Lightning rends ſome bodies. The electrical ſpark will ſtrike a hole thro' a quire of ſtrong paper.

56. If the ſource of lightning, aſſigned in this paper, be the true one, there ſhould be little thunder heard at ſea far from land. And accordingly ſome old ſea-captains, of whom enquiry has been made, do affirm, that the fact agrees perfectly with the hypotheſis; for that, in croſſing the great ocean, they ſeldom meet with thunder till they come into ſoundings; and that the iſlands far from the continent have very little of it. And a curious obſerver, who lived 13 years at *Bermudas*, ſays, there was leſs thunder there in that whole time than he has ſometimes heard in a month at *Carolina*.

ADDITIONAL PAPERS

TO

PETER COLLINSON, Eſq; F. R. S. *London.*

SIR, PHILADELPHIA, *July* 29, 1750.

AS you firſt put us on electrical experiments, by ſending to our library company a tube, with directions how to uſe it; and as our honourable proprietary enabled us to carry thoſe experiments to a greater height, by this generous preſent of a compleat electrical apparatus; 'tis fit that both ſhould know from time to time what progreſs we make. It was in this view I wrote and ſent you my former papers on this ſubject, deſiring, that as I had not the honour of a direct correſpondence with that bountiful benefactor to our library, they might be communicated to him through your hands. In the ſame view I write, and ſend you this additional paper. If it happens to bring you nothing new (which may well be, conſidering the number of ingenious men in *Europe*, continually engaged in the ſame reſearches) at leaſt it will ſhow, that the inſtruments put into our hands, are not neglected; and, that if no valuable diſcoveries are made by us, whatever the cauſe may be, it is not want of induſtry and application.

I am, Sir,

Your much obliged

Humble Servant,

B. FRANKLIN.

OPINIONS *and* CONJECTURES, *concerning the Properties and Effects of the electrical Matter, ariſing from Experiments and Obſervations, made at* Philadelphia, 1749.

§ 1. THE electrical matter conſiſts of particles extremely ſubtile, ſince it can permeate common matter, even the denſeſt metals, with ſuch eaſe and freedom, as not to receive any perceptible reſiſtance.

2. If any one ſhould doubt, whether the electrical matter paſſes thro' the ſubſtance of bodies, or only over and along their ſurfaces, a ſhock from an electrified large glaſs jar, taken through his own body, will probably convince him.

3. Electrical matter differs from common matter in this, that the parts of the latter mutually attract, thoſe of the former mutually repel, each other. Hence the appearing divergency in a ſtream of electrified effluvia.

4. But though the particles of electrical matter do repel each other, they are ſtrongly attracted by all other matter.*

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* See the ingenious eſſays on Electricity in the Tranſactions, by Mr *Ellicot*.

5. From theſe three things, the extreme ſubtility of the electrical matter, the mutual repulſion of its parts, and the ſtrong attraction between them and other matter, ariſe this effect, that when a quantity of electrical matter is applied to a maſs of common matter, of any bigneſs or length within our obſervation (which has not already got its quantity) it is immediately and equally diffuſed through the whole.

6. Thus common matter is a kind of ſpunge to the electrical fluid. And as a ſpunge would receive no water, if the parts of water were not ſmaller than the pores of the ſpunge; and even then but ſlowly, if there were not a mutual attraction between thoſe parts and the parts of the ſpunge; and would ſtill imbibe it faſter, if the mutual attraction among the parts of the water did not impede, ſome force being required to ſeparate them, and faſteſt, if, inſtead of attraction, there were a mutual repulſion among thoſe parts, which would act in conjunction with the attraction of the ſpunge. So is the caſe between the electrical and common matter.

7. But in common matter there is (generally) as much of the electrical, as it will contain within its ſubſtance. If more is added, it lies without upon the ſurface, and forms, what we call an electrical atmoſphere: and then the body is ſaid to be electrified.

8. 'Tis ſuppoſed, that all kinds of common matter do not attract and retain the electrical, with equal ſtrength and force; for reaſons to be given hereafter. And that thoſe

called electrics *per ſe*, as glaſs, &c. attract and retain it ſtrongeſt, and contain the greateſt quantity.

9. We know that the electrical fluid is *in* common matter, becauſe we can pump it *out* by the globe or tube. We know that common matter has near as much as it can contain, becauſe, when we add a little more to any portion of it, the additional quantity does not enter, but forms an electrical atmoſphere. And we know that common matter has not (generally) more than it can contain, otherwiſe all looſe portions of it would repel each other, as they conſtantly do when they have electric atmoſpheres.

10. The beneficial uſes of this electrical fluid in the creation, we are not yet well acquainted with, though doubtleſs ſuch there are, and thoſe very conſiderable; but we may ſee ſome pernicious conſequences, that would attend a much greater proportion of it. For had this globe we live on as much of it in proportion as we can give to a globe of iron, wood, or the like, the particles of duſt and other light matters that get looſe from it, would, by virtue of their ſeparate electrical atmoſpheres, not only repel each other, but be repelled from the earth, and not eaſily be brought to unite with it again; whence our air would continually be more and more clogged with foreign matter, and grow unfit for reſpiration. This affords another occaſion of adoring that wiſdom which has made all things by weight and meaſure!

11. If a piece of common matter be ſuppoſed entirely free from electrical matter, and a ſingle particle of the

latter be brought nigh, 'twill be attracted and enter the body, and take place in the center, or where the attraction is every way equal. If more particles enter, they take their places where the balance is equal between the attraction of the common matter and their own mutual repulſion. 'Tis ſuppoſed they form triangles, whoſe ſides ſhorten as their number increaſes; 'till the common matter has drawn in ſo many, that its whole power of compreſſing thoſe triangles by attraction, is equal to their whole power of expanding themſelves by repulſion; and then will ſuch piece of matter receive no more.

12. When part of this natural proportion of electrical fluid is taken out of a piece of common matter, the triangles formed by the remainder, are ſuppoſed to widen by the mutual repulſion of the parts, until they occupy the whole piece.

13. When the quantity of electrical fluid taken from a piece of common matter is reſtored again, it enters, the expanded triangles being again compreſſed till there is room for the whole.

14. To explain this: take two apples, or two balls of wood or other matter, each having its own natural quantity of the electrical fluid. Suſpend them by ſilk lines from the cieling. Apply the wire of a well-charged vial, held in your hand, to one of them (A) *Fig.* 7. and it will receive from the wire a quantity of the electrical fluid; but will not imbibe it, being already full. The fluid therefore will flow round its ſurface, and form an electrical atmoſphere.

Bring A into contact with B, and half the electrical fluid is communicated, ſo that each has now an electrical atmoſphere, and therefore they repel each other. Take away theſe atmoſpheres by touching the balls, and leave them in their natural ſtate: then, having fixed a ſtick of ſealing-wax to the middle of the vial to hold it by, apply the wire to A, at the ſame time the coating touches B. Thus will a quantity of the electrical fluid be drawn out of B, and thrown on A. So that A will have a redundance of this fluid, which forms an atmoſphere round it, and B an exactly equal deficiency. Now bring theſe balls again into contact, and the electrical atmoſphere will not be divided between A and B, into two ſmaller atmoſpheres as before; for B will drink up the whole atmoſphere of A, and both will be found again in their natural ſtate.

15. The form of the electrical atmoſphere is that of the body it ſurrounds. This ſhape may be rendered viſible in a ſtill air, by raiſing a ſmoke from dry roſin, dropt into a hot tea-ſpoon under the electriſed body, which will be attracted and ſpread itſelf equally on all ſides, covering and concealing the body. And this form it takes, becauſe it is attracted by all parts of the ſurface of the body, tho' it cannot enter the ſubſtance already replete. Without this attraction it would not remain round the body, but diſſipate in the air.

16. The atmoſphere of electrical particles ſurrounding an electrified ſphere, is not more diſpoſed to leave it or

more eaſily drawn off from any one part of the ſphere than from another, becauſe it is equally attracted by every part. But that is not the caſe with bodies of any other figure. From a cube it is more eaſily drawn at the corners than at the plane ſides, and ſo from the angles of a body of any other form, and ſtill moſt eaſily from the angle that is moſt acute. Thus if a body ſhaped as A,B,C,D,E, in Fig. 8. be electrified, or have an electrical atmoſphere communicated to it, and we conſider every ſide as a baſe on which the particles reſt, and by which they are attracted, one may ſee, by imagining a line from A to F, and another from E to G, that the portion of the atmoſphere included in F, A, E, G, has the line A, E, for its baſis. So the portion of atmoſphere included in H, A, B, I, has the line A, B, for its baſis. And likewiſe the portion included in K, B, C, L, has B, C, to reſt on; and ſo on the other ſide of the figure. Now if you would draw off this atmoſphere with any blunt ſmooth body, and approach the middle of the ſide A, B, you muſt come very near before the force of your attracter exceeds the force or power with which that ſide holds its atmoſphere. But there is a ſmall portion between I, B, K, that has leſs of the ſurface to reſt on, and to be attracted by, than the neighbouring portions, while at the ſame time there is a mutual repulſion between its particles and the particles of thoſe portions, therefore here you can get it with more eaſe, or at a greater diſtance. Between F, A, H, there is a larger portion that has yet a leſs ſurface to reſt on and to attract it;

here therefore you can get it away ſtill more eaſily. But eaſieſt of all between L,C,M, where the quantity is largeſt, and the ſurface to attract and keep it back the leaſt. When you have drawn away one of theſe angular portions of the fluid, another ſucceeds in its place, from the nature of fluidity and the mutual repulſion beforementioned; and ſo the atmoſphere continues flowing off at ſuch angle, like a ſtream, till no more is remaining. The extremities of the portions of atmoſphere over theſe angular parts are likewiſe at a greater diſtance from the electrified body, as may be ſeen by the inſpection of the above figure; the point of the atmoſphere of the angle C, being much farther from C, than any other part of the atmoſphere over the lines C, B, or B, A: And, beſides the diſtance ariſing from the nature of the figure, where the attraction is leſs, the particles will naturally expand to a greater diſtance by their mutual repulſion. On theſe accounts we ſuppoſe electrified bodies diſcharge their atmoſpheres upon unelectrified bodies more eaſily and at a greater diſtance from their angles and points than from their ſmooth ſides.— Thoſe points will alſo diſcharge into the air, when the body has too great an electrical atmoſphere, without bringing any non-electric near, to receive what is thrown off: For the air, though an electric *per ſe*, yet has always more or leſs water and other non-electric matters mixed with it; and theſe attract and receive what is ſo diſcharged.

17. But points have a property, by which they *draw on* as well as *throw off* the electrical fluid, at greater diſtances

than

than blunt bodies can. That is, as the pointed part of an electrified body will diſcharge the atmoſphere of that body, or communicate it fartheſt to another body, ſo the point of an unelectrified body, will draw off the electrical atmoſphere from an electrified body, farther than a blunter part of the ſame unelectrified body will do. Thus a pin held by the head, and the point preſented to an electrified body, will draw off its atmoſphere at a foot diſtance; where, if the head were preſented inſtead of the point, no ſuch effect would follow. To underſtand this, we may conſider, that if a perſon ſtanding on the floor would draw off the electrical atmoſphere from an electrified body, an iron crow and a blunt knitting-needle held alternately in his hand and preſented for that purpoſe, do not draw with different forces in proportion to their different maſſes. For the man, and what he holds in his hand, be it large or ſmall, are connected with the common maſs of unelectrified matter; and the force with which he draws is the ſame in both caſes, it conſiſting in the different proportion of electricity in the electrified body and that common maſs. But the force with which the electrified body retains its atmoſphere by attracting it, is proportioned to the ſurface over which the particles are placed; *i. e.* four ſquare inches of that ſurface retain their atmoſphere with four times the force that one ſquare inch retains its atmoſphere. And as in plucking the hairs from the horſe's tail, a degree of ſtrength ſufficient to pull away a handful at once, could yet eaſily ſtrip it hair by hair; ſo a blunt body preſented cannot draw off a number of particles at once, but a pointed one, with no greater force, takes them away eaſily, particle by particle.

18. Theſe explanations of the power and operation of points, when they firſt occurr'd to me, and while they firſt floated in my mind, appeared perfectly ſatisfactory; but now I have wrote them, and conſidered them more cloſely in black and white, I muſt own I have ſome doubts about them: yet, as I have at preſent nothing better to offer in their ſtead, I do not croſs them out: for even a bad ſolution read, and its faults diſcovered, has often given riſe to a good one in the mind of an ingenious reader.

19. Nor is it of much importance to us, to know the manner in which nature executes her laws; 'tis enough if we know the laws themſelves. 'Tis of real uſe to know, that china left in the air unſupported will fall and break; but *how* it comes to fall, and *why* it breaks, are matters of ſpeculation. 'Tis a pleaſure indeed to know them, but we can preſerve our china without it.

20. Thus in the preſent caſe, to know this power of points, may poſſibly be of ſome uſe to mankind, though we ſhould never be able to explain it. The following experiments, as well as thoſe in my firſt paper, ſhow this power. I have a large prime conductor made of ſeveral thin ſheets of Fuller's paſteboard form'd into a tube, near ten feet long and a foot diameter. It is cover'd with *Dutch* emboſs'd paper, almoſt totally gilt. This large

metallic

metallic ſurface ſupports a much greater electrical atmoſphere than a rod of iron of 50 times the weight would do. It is ſuſpended by ſilk lines, and when charged will ſtrike at near two inches diſtance, a pretty hard ſtroke, ſo as to make one's knuckle ach. Let a perſon ſtanding on the floor preſent the point of a needle at 12 or more inches diſtance from it, and while the needle is ſo preſented, the conductor cannot be charged, the point drawing off the fire as faſt as it is thrown on by the electrical globe. Let it be charged, and then preſent the point at the ſame diſtance, and it will ſuddenly be diſcharged. In the dark you may ſee a light on the point, when the experiment is made. And if the perſon holding the point ſtands upon wax, he will be electrified by receiving the fire at that diſtance. Attempt to draw off the electricity with a blunt body, as a bolt of iron round at the end, and ſmooth (a ſilverſmith's iron punch, inch thick, is what I uſe) and you muſt bring it within the diſtance of three inches before you can do it, and then it is done with a ſtroke and crack. As the paſteboard tube hangs looſe on ſilk lines, when you approach it with the punch iron, it likewiſe will move towards the punch, being attracted while it is charged; but if, at the ſame inſtant, a point be preſented as before, it retires again, for the point diſcharges it. Take a pair of large braſs ſcales, of two or more feet beam, the cords of the ſcales being ſilk. Suſpend the beam by a packthread from the cieling, ſo that the bottom of the ſcales may be about a foot from the floor: The ſcales will move round in a circle by the untwiſting of the packthread. Set the iron punch on the end upon the floor, in ſuch a place as that the ſcales may paſs over it in making their circle: Then electrify one ſcale by applying the wire of a charged phial to it. As they move round, you ſee that ſcale draw nigher to the floor, and dip more when it comes over the punch; and if that be placed at a proper diſtance, the ſcale will ſnap and diſcharge its fire into it. But if a needle be ſtuck on the end of the punch, its point upwards, the ſcale, inſtead of drawing nigh to the punch, and ſnapping, diſcharges its fire ſilently through the point, and riſes higher from the punch. Nay, even if the needdle be placed upon the floor near the punch, its point upwards, the end of the punch, tho' ſo much higher than the needle, will not attract the ſcale and receive its fire, for the needle will get it and convey it away, before it comes nigh enough for the punch to act. And this is conſtantly obſervable in theſe experiments, that the greater quantity of electricity on the paſteboard tube, the farther it ſtrikes or diſcharges its fire, and the point likewiſe will draw it off at a ſtill greater diſtance.

Now if the fire of electricity and that of lightning be the ſame, as I have endeavoured to ſhow at large, in a former paper, this paſteboard tube and theſe ſcales may repreſent electrified clouds. If a tube of only ten feet long will ſtrike and diſcharge its fire on the punch at two or three inches diſtance, an electrified cloud of perhaps 10,000 acres, may ſtrike and diſcharge on the earth at a proportionably greater diſtance. The horizontal motion of the ſcales over the floor, may repreſent the motion of the clouds over the earth; and the erect iron punch, a hill or high building; and then we ſee how electrified clouds paſſing over hills or high builders at too great a height to ſtrike, may be attracted lower till within their ſtriking diſtance. And laſtly, if a needle fix'd on the punch with its point upright, or even on the floor below the punch, will draw the fire from the ſcale ſilently at a much greater than the ſtriking diſtance, and ſo prevent its deſcending towards the punch; or if in its courſe it would have come nigh enough to ſtrike, yet being firſt deprived of its fire it cannot, and the punch is thereby ſecured from the ſtroke. I ſay, if theſe things are ſo, may not the knowledge of this power of points be of uſe to mankind, in preſerving houſes, churches, ſhips, *&c.* from the ſtroke of lightning, by directing us to fix on the higheſt parts of thoſe edifices, upright rods of iron made ſharp as a needle, and gilt to prevent ruſting, and from the foot of thoſe rods a wire down the outſide of the building into the ground, or down round one of the ſhrouds of a ſhip, and down her ſide till it reaches the water? Would not theſe pointed rods probably draw the electrical fire ſilently out of a cloud before it came nigh enough to ſtrike, and thereby ſecure us from that moſt ſudden and terrible miſchief?

21. To determine the queſtion, whether the clouds

that contain lightning are electrified or not, I would propoſe an experiment to be try'd where it may be done conveniently. On the top of ſome high tower or ſteeple, place a kind of ſentry-box, (as in FIG. 9.) big enough to contain a man and an electrical ſtand. From the middle of the ſtand, let an iron rod riſe and paſs bending out of the door, and then upright 20 or 30 feet, pointed very ſharp at the end. If the electrical ſtand be kept clean and dry, a man ſtanding on it when ſuch clouds are paſſing low, might be electrified and afford ſparks, the rod drawing fire to him from a cloud. If any danger to the man ſhould be apprehended (though I think there would be none) let him ſtand on the floor of his box, and now and then bring near to the rod the loop of a wire that has one end faſtened to the leads, he holding it by a wax handle; ſo the ſparks, if the rod is electrified, will ſtrike from the rod to the wire, and not affect him.

22. Before I leave this ſubject of lightning, I may mention ſome other ſimilarities between the effects of that, and theſe of electricity. Lightning has often been known to ſtrike people blind. A pigeon that we ſtruck dead to appearance by the electrical ſhock, recovering life, droop'd about the yard ſeveral days, eat nothing though crumbs were thrown to it, but declined and died. We did not think of its being deprived of ſight; but afterwards a pullet ſtruck dead in like manner, being recovered by repeatedly blowing into its lungs, when ſet down on the floor, ran headlong againſt the wall, and on examination

appeared perfectly blind. Hence we concluded that the pigeon alſo had been abſolutely blinded by the ſhock. The biggeſt animal we have yet killed or try'd to kill with the electrical ſtroke, was a well-grown pullet.

23. Reading in the ingenious Dr. *Hales*'s account of the thunder ſtorm at *Stretham*, the effect of the lightning in ſtripping off all the paint that had covered a gilt moulding of a pannel of wainſcot, without hurting the reſt of the paint, I had a mind to lay a coat of paint over the filleting of gold on the cover of a book, and try the effect of a ſtrong electrical flaſh ſent through that gold from a charged ſheet of glaſs. But having no paint at hand, I paſted a narrow ſtrip of paper over it; and when dry, ſent the flaſh through the gilding; by which the paper was torn off from end to end, with ſuch force, that it was broke in ſeveral places, and in others brought away part of the grain of the Turky-leather in which it was bound; and convinced me, that had it been painted, the paint would have been ſtript off in the ſame manner with that on the wainſcot at *Stretham*.

24. Lightning melts metals, and I hinted in my paper on that ſubject, that I ſuſpected it to be a cold fuſion; I do not mean a fuſion by force of cold, but a fuſion without heat. We have alſo melted gold, ſilver, and copper, in ſmall quantities, by the electrical flaſh. The manner is this: Take leaf gold, leaf ſilver, or leaf gilt copper, commonly called leaf braſs, or *Dutch* gold: cut off from the leaf long narrow ſtrips the breadth of a ſtraw.

a ſtraw. Place one of theſe ſtrips between two ſtrips of ſmooth glaſs that are about the width of your finger. If one ſtrip of gold, the length of the leaf, be not long enough for the glaſs, add another to the end of it, ſo that you may have a little part hanging out looſe at each end of the glaſs. Bind the pieces of glaſs together from end to end with ſtrong ſilk thread; then place it ſo as to be part of an electrical circle, (the ends of gold hanging out being of uſe to join with the other parts of the circle) and ſend the flaſh through it, from a large electrified jar or ſheet of glaſs. Then if your ſtrips of glaſs remain whole, you will ſee that the gold is miſſing in ſeveral places, and inſtead of it a metallic ſtain on both the glaſſes; the ſtains on the upper and under glaſs exactly ſimilar in the minuteſt ſtroke, as may be ſeen by holding them to the light; the metal appeared to have been not only melted, but even vetrified, or otherwiſe ſo driven into the pores of the glaſs, as to be protected by it from the action of the ſtrongeſt *Aqua Fortis* or *Aqua Regia*. I ſend you encloſed two little pieces of glaſs with theſe metallic ſtains upon them, which cannot be removed without taking part of the glaſs with them. Sometimes the ſtain ſpreads a little wider than the breadth of the leaf, and looks brighter at the edge, as by inſpecting cloſely you may obſerve in theſe. Sometimes the glaſs breaks to pieces: once the upper glaſs broke into a thouſand pieces, looking like coarſe ſalt. Theſe pieces I ſend you were ſtain'd with *Dutch* gold. True gold makes a darker ſtain,

ſomewhat

ſomewhat reddiſh; ſilver, a greeniſh ſtain. We once took two pieces of thick looking-glaſs, as broad as a Gunter's ſcale, and 6 inches long; and placing leaf-gold between them, put them betwixt two ſmoothly plain'd pieces of wood, and fix'd them tight in a book-binder's ſmall preſs; yet though they were ſo cloſely confined, the force of the electrical ſhock ſhivered the glaſs into many pieces. The gold was melted and ſtain'd into the glaſs as uſual. The circumſtances of the breaking of the glaſs differ much in making the experiment, and ſometimes it does not break at all: but this is conſtant, that the ſtains in the upper and under pieces are exact counterparts of each other. And though I have taken up the pieces of glaſs between my fingers immediately after this melting, I never could perceive the leaſt warmth in them.

25. In one of my former papers, I mention'd, that gilding on a book, though at firſt it communicated the ſhock perfectly well, yet fail'd after a few experiments, which we could not account for. We have ſince found, that one ſtrong ſhock breaks the continuity of the gold in the filleting, and makes it look rather like duſt of gold, abundance of its parts being broken and driven off; and it will ſeldom conduct above one ſtrong ſhock. Perhaps this may be the reaſon: When there is not a perfect continuity in the circle, the fire muſt leap over the vacancies; there is a certain diſtance which it is able to leap over according to its ſtrength; if a number of ſmall vacancies, though each be very minute, taken to-

gether exceed that diſtance, it cannot leap over them, and ſo the ſhock is prevented.

26. From the before-mentioned law of electricity, that points, as they are more or leſs acute, draw on and throw off the electrical fluid with more or leſs power, and at greater or leſs diſtances, and in larger or ſmaller quantities in the ſame time, we may ſee how to account for the ſituation of the leaf of gold ſuſpended between two plates, the upper one continually electrified, the under one in a perſon's hand ſtanding on the floor. When the upper plate is electrified, the leaf is attracted and raiſed towards it, and would fly to that plate, were it not for its own points. The corner that happens to be uppermoſt when the leaf is riſing, being a ſharp point, from the extream thinneſs of the gold, draws and receives at a diſtance a ſufficient quantity of the electrical fluid to give itſelf an electrical atmoſphere, by which its progreſs to the upper plate is ſtopt, and it begins to be repelled from that place, and would be driven back to the under plate, but that its loweſt corner is likewiſe a point, and throws off or diſcharges the overplus of the leaf's atmoſphere, as faſt as the upper corner draws it on. Were theſe two points perfectly equal in acuteneſs, the leaf would take place exactly in the middle ſpace, for its weight is a trifle, compared to the power acting on it: But it is generally neareſt the unelectrified plate, becauſe, when the leaf is offered to the electrified plate at a diſtance, the ſharpeſt point is commonly firſt affected and raiſed towards it; ſo that point, from its greater

acuteneſs, receiving the fluid faſter than its oppoſite can diſcharge it at equal diſtanees, it retires from the electrified plate, and draws nearer to the unelectrified plate, till it comes to a diſtance where the diſcharge can be exactly equal to the receipt, the latter being leſſened, and the former encreaſed; and there it remains as long as the globe continues to ſupply freſh electrical matter. This will appear plain, when the difference of acuteneſs in the corners is made very great. Cut a piece of *Dutch* gold (which is fitteſt for theſe experiments on account of its greater ſtrength) into the form of FIG. 10. the upper corner a right angle, the two next obtuſe angles, and the loweſt a very acute one; and bring this on your plate under the electrified plate, in ſuch a manner as that the right-angled part may be firſt raiſed (which is done by covering the acute part with the hollow of your hand) and you will ſee this leaf take place much nearer to the upper than the under plate; becauſe without being nearer, it cannot receive ſo faſt at its right-angled point, as it can diſcharge at its acute one. Turn this leaf with the acute part uppermoſt, and then it takes place neareſt the unelectrified plate; becauſe, otherwiſe it receives faſter at its acute point than it can diſcharge at its right-angled one. Thus the difference of diſtance is always proportioned to the difference of acuteneſs. Take care in cutting your leaf to leave no little ragged particles on the edges, which ſometimes form points where you would not have them. You may make this figure ſo acute below and blunt above, as to need no under plate, it diſcharging faſt enough into the air. When it is made narrower, as the figure between the pricked lines, we call it the *Golden Fiſh*, from its manner of acting. For if you take it by the tail, and hold it at a foot or greater horizontal diſtance from the prime conductor, it will, when let go, fly to it with a briſk but wavering motion, like that of an eel through the water; it will then take place under the prime conductor, at perhaps a quarter or half an inch diſtance, and keep a continual ſhaking of its tail like a fiſh, ſo that it ſeems animated. Turn its tail towards the prime conductor, and then it flies to your finger, and ſeems to nibble it. And if you hold a plate under it at ſix or eight inches diſtance, and ceaſe turning the globe, when the electrical atmoſphere of the conductor grows ſmall, it will deſcend to the plate and ſwim back again ſeveral times with the ſame fiſh-like motion, greatly to the entertainment of ſpectators. By a little practice in blunting or ſharpening the heads or tails of theſe figures, you may make them take place as deſired, nearer, or farther from the electrified plate.

27. It is ſaid in ſection 8, of this paper, that all kinds of common matter are ſuppoſed not to attract the electrical fluid with equal ſtrength; and that thoſe called electrics *per ſe*, as glaſs, &c. attract and retain it ſtrongeſt, and contain the greateſt quantity. This latter poſition may ſeem a paradox to ſome, being contrary to the hitherto received opinion; and therefore I ſhall now endeavour to explain it.

28. In order to this, let it firſt be conſider'd, *that we cannot by any means we are yet acquainted with, force the electrical fluid thro' glaſs.* I know it is commonly thought that it eaſily prevades glaſs, and the experiment of a feather ſuſpended by a thread in a bottle hermetically ſealed, yet moved by bringing a rubbed tube near the outſide of the bottle, is alledged to prove it. But, if the electrical fluid ſo eaſily pervades glaſs, how does the vial become *charged* (as we term it) when we hold it in our hands? Would not the fire thrown in by the wire paſs through to our hands, and ſo eſcape into the floor? Would not the bottle in that caſe be left juſt as we found it, uncharged, as we know a metal bottle ſo attempted to be charged would be? Indeed, if there be the leaſt crack, the minuteſt ſolution of continuity in the glaſs, though it remains ſo tight that nothing elſe we know of will paſs, yet the extremely ſubtile electrical fluid flies through ſuch a crack with the greateſt freedom, and ſuch a bottle we know can never be charged: What then makes the difference between ſuch a bottle and one that is ſound, but this, that the fluid can paſs through the one, and not through the other[*]?

29. It is true, there is an experiment that at firſt ſight would be apt to ſatisfy a ſlight obſerver, that the fire thrown into the bottle by the wire, does really paſs thro'

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[*] See the firſt ſixteen Sections of the former paper, called *Farther Experiments*, &c.

the glaſs. It is this: place the bottle on a glaſs ſtand, under the prime conductor; ſuſpend a bullet by a chain from the prime conductor, till it comes within a quarter of an inch right over the wire of the bottle; place your knuckle on the glaſs ſtand, at juſt the ſame diſtance from the coating of the bottle, as the bullet is from its wire. Now let the globe be turned, and you ſee a ſpark ſtrike from the bullet to the wire of the bottle, and the ſame inſtant you ſee and feel an exactly equal ſpark ſtriking from the coating on your knuckle, and ſo on ſpark for ſpark. This looks as if the whole received by the bottle was again diſcharged from it. And yet the bottle by this means is charged! * And therefore the fire that thus leaves the bottle, though the ſame in quantity, cannot be the very ſame fire that entered at the wire; for if it were, the bottle would remain uncharged.

30. If the fire that ſo leaves the bottle be not the ſame that is thrown in through the wire, it muſt be fire that ſubſiſted in the bottle, (that is, in the glaſs of the bottle) before the operation began.

31. If ſo, there muſt be a great quantity in glaſs, becauſe a great quantity is thus diſcharged even from very thin glaſs.

32. That this electrical fluid or fire is ſtrongly attracted by glaſs, we know from the quickneſs and violence with which it is reſumed by the part that had been deprived of

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* See Sect. 10. of *Farther Experiments*, &c.

it, when there is an opportunity. And by this, that we cannot from a maſs of glaſs draw a quantity of electrical fire, or electrify the whole maſs *minus*, as we can a maſs of metal. We cannot leſſen or increaſe its whole quantity, for the quantity it has it holds; and it has as much as it can hold. Its pores are filled with it as full as the mutual repellency of the particles will admit; and what is already in, refuſes, or ſtrongly repels, any additional quantity. Nor have we any way of moving the electrical fluid in glaſs, but one; that is, by covering part of the two ſurfaces of thin glaſs with non-electrics, and then throwing an additional quantity of this fluid on one ſurface, which ſpreading in the non-electric, and being bound by it to that ſurface, acts by its repelling force on the particles of the electrical fluid contained in the other ſurface, and drives them out of the glaſs into the non-electric on that ſide, from whence they are diſcharged, and then thoſe added on the charged ſide can enter. But when this is done, there is no more in the glaſs, nor leſs than before, juſt as much having left it on one ſide as it received on the other.

33. I feel a want of terms here, and doubt much whether I ſhall be able to make this part intelligible. By the word *ſurface*, in this caſe, I do not mean mere length and breadth without thickneſs; but when I ſpeak of the upper or under ſurface of a piece of glaſs, the outer or inner ſurface of the vial, I mean length, breadth, and half the thickneſs, and beg the favour of being ſo underſtood. Now, I ſuppoſe, that glaſs in its firſt principles, and in the

furnace, has no more of this electrical fluid than other common matter: That when it is blown, as it cools, and the particles of common fire leave it, its pores become a vacuum: That the component parts of glaſs are extremely ſmall and fine, I gueſs from its never ſhowing a rough face when it breaks, but always a poliſh; and from the ſmallneſs of its particles I ſuppoſe the pores between them muſt be exceeding ſmall, which is the reaſon that aqua-fortis, nor any other menſtruum we have, can enter to ſeparate them and diſſolve the ſubſtance; nor is any fluid we know of, fine enough to enter, except common fire, and the electrical fluid. Now the departing fire leaving a vacuum, as aforeſaid, between theſe pores, which air nor water are fine enough to enter and fill, the electrical fluid (which is every where ready in what we call the non-electrics, and in the non-electric Mixtures that are in the air) is attracted in: yet does not become fixed with the ſubſtance of the glaſs, but ſubſiſts there as water in a porous ſtone, retained only by the attraction of the fixed parts, itſelf ſtill looſe and a fluid. But I ſuppoſe farther, that in the cooling of the glaſs, its texture becomes cloſeſt in the middle, and forms a kind of partition, in which the pores are ſo narrow, that the particles of the electrical fluid, which enter both ſurfaces at the ſame time, cannot go through, or paſs and repaſs from one ſurface to the other, and ſo mix together; yet, though the particles of electrical fluid, imbibed by each ſurface, cannot themſelves paſs through to thoſe of the other, their repellency can, and by this means they act on one another. The particles of the electrical fluid have a mutual repellency, but by the power of attraction in the glaſs they are condenſed or forced nearer to each other. When the glaſs has received, and, by its attraction, forced cloſer together ſo much of this electrical fluid, as that the power of attracting and condenſing in the one, is equal to the power of expanſion in the other, it can imbibe no more, and that remains its conſtant whole quantity; but each ſurface would receive more, if the repellencey of what is in the oppoſite ſurface did not reſiſt its entrance. The quantities of this fluid in each ſurface being equal, their repelling action on each other is equal; and therefore thoſe of one ſurface cannot drive out thoſe of the other: but, if a greater quantity is forced into one ſurface than the glaſs would naturally draw in; this increaſes the repelling power on that ſide, and overpowering the attraction on the other, drives out part of the fluid that had been imbibed by that ſurface, if there be any non-electric ready to receive it: ſuch there is in all caſes where glaſs is electrified to give a ſhock. The ſurface that has been thus emptied by having its electrical fluid driven out, reſumes again an equal quantity with violence, as ſoon as the glaſs has an opportunity to diſcharge that over quantity more than it could retain by attraction in its other ſurface, by the additional repellency of which the vacuum had been occaſioned. For experiments favouring (if I may not ſay confirming) this hypotheſis, I muſt, to avoid repetition, beg leave to refer you back to what is ſaid of the electrical phial in my former papers.

34. Let us now ſee how it will account for ſeveral other appearances.—Glaſs, a body extremely elaſtic (and perhaps its elaſticity may be owing in ſome degree to the ſubſiſting of ſo great a quantity of this repelling fluid in its pores) muſt, when rubbed, have its rubbed ſurface ſomewhat ſtretched, or its ſolid parts drawn a little farther aſunder, ſo that the vacancies in which the electrical fluid reſides, become larger, affording room for more of that fluid, which is immediately attracted into it from the cuſhion or hand rubbing, they being ſupply'd from the common ſtock. But the inſtant the parts of the glaſs ſo open'd and fill'd have paſs'd the friction, they cloſe again, and force the additional quantity out upon the ſurface, where it muſt reſt till that part comes round to the cuſhion again, unleſs ſome non-electric (as the prime conductor) firſt preſents to receive it.* But if the inſide of the globe be lined with a non-electric, the ad-

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* In the dark the electrical fluid may be ſeen on the cuſhion in two ſemi-circles or half-moons, one on the fore part, the other on the back part of the cuſhion, juſt where the globe and cuſhion ſeparate. In the fore creſcent the fire is paſſing out of the cuſhion into the glaſs; in the other it is leaving the glaſs, and returning into the back part of the cuſhion. When the prime conductor is apply'd to take it off the glaſs, the back creſcent diſappears.

ditional repellency of the electrical fluid, thus collected by friction on the rubb'd part of the globe's outer ſurface, drives an equal quantity out of the inner ſurface into that non-electric lining, which receiving it, and carrying it away from the rubb'd part into the common maſs, through the axis of the globe and frame of the machine, the new collected electrical fluid can enter and remain in the outer ſurface, and none of it (or a very little) will be received by the prime conductor. As this charg'd part of the globe comes round to the cuſhion again, the outer ſurface delivers its overplus fire into the cuſhion, the oppoſite inner ſurface receiving at the ſame time an equal quantity from the floor. Every electrician knows that a globe wet within will afford little or no fire, but the reaſon has not before been attempted to be given, that I know of.

34. So if a tube lined with a * non-electric, be rubb'd, little or no fire is obtained from it. What is collected from the hand in the downward rubbing ſtroke, entering the pores of the glaſs, and driving an equal quantity out of the inner ſurface into the non-electric lining: and the hand in paſſing up to take a ſecond ſtroke, takes out again what had been thrown into the outer ſurface, and then the inner ſurface receives back again what it had given to the non-electric lining. Thus the particles of

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* Gilt paper, with the gilt face next the glaſs, does well.

electrical fluid belonging to the inſide ſurface go in and out of their pores every ſtroke given to the tube. Put a wire into the tube, the inward end in contact with the non-electric lining, ſo it will repreſent the *Leyden* bottle. Let a ſecond perſon touch the wire while you rub, and the fire driven out of the inward ſurface when you give the ſtroke, will paſs through him into the common maſs, and return through him when the inner ſurface reſumes its quantity, and therefore this new kind of *Leyden* bottle cannot ſo be charged. But thus it may: after every ſtroke, before you paſs your hand up to make another, let the ſecond perſon apply his finger to the wire, take the ſpark, and then withdraw his finger; and ſo on till he has drawn a number of ſparks; thus will the inner ſurface be exhauſted, and the outer ſurface charged; then wrap a ſheet of gilt paper cloſe round the outer ſurface, and graſping it in your hand you may receive a ſhock, by applying the finger of the other hand to the wire: for now the vacant pores in the inner ſurface reſume their quantity, and the overcharg'd pores in the outer ſurface diſcharge that overplus; the equilibrium being reſtored through your body, which could not be reſtored through the glaſs.* If the tube be exhauſted of air, a non-electric lining in contact with the wire is not neceſſary; for *in vacuo*, the electrical fire will fly freely from the inner ſurface, without a non-electric conductor: but air reſiſts its motion; for being itſelf an electric *per ſe*, it does not attract it, having already its quantity. So the air never draws off an electric atmoſphere from any body, but in proportion to the non-electrics mix'd with it: it rather keeps ſuch an atmoſphere confin'd, which from the mutual repulſion of its particles, tends to diſſipation, and would immediately diſſipate *in vacuo*.—And thus the experiment of the feather incloſed in a glaſs veſſel hermetically ſealed, but moving on the approach of the rubbed tube, is explained: When an additional quantity of the electrical fluid is applied to the ſide of the veſſel by the atmoſphere of the tube, a quantity is repelled and driven out of the inner ſurface of that ſide into the veſſel, and there affects the feather, returning again into its pores, when the tube with its atmoſphere is withdrawn; not that the particles of that atmoſphere did themſelves paſs through the glaſs to the feather.—And every other appearance I have yet ſeen, in which glaſs and electricity are concern'd, are, I think, explained with equal eaſe by the ſame hypotheſis. Yet, perhaps, it may not be a true one, and I ſhall be obliged to him that affords me a better.

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* See *Farther Experiments*, §. 15.

35. Thus I take the difference between non-electrics and glaſs, an electric *per ſe*, to conſiſt in theſe two particulars. 1ſt, That a non-electric eaſily ſuffers a change in the quantity of the electrical fluid it contains. You

may leſſen its whole quantity by drawing out a part, which the whole body will again reſume; but of glaſs you can only leſſen the quantity contained in one of its ſurfaces; and not that, but by ſupplying an equal quantity at the ſame time to the other ſurface; ſo that the whole glaſs may always have the ſame quantity in the two ſurfaces, their two different quantities being added together. And this can only be done in glaſs that is thin; beyond a certain thickneſs we have yet no power that can make this change. And, 2dly, that the electrical fire freely removes from place to place, in and through the ſubſtance of a non-electric, but not ſo through the ſubſtance of glaſs. If you offer a quantity to one end of a long rod of metal, it receives it, and when it enters, every particle that was before in the rod, puſhes its neighbour quite to the further end, where the overplus is diſcharged; and this inſtantaneouſly where the rod is part of the circle in the experiment of the ſhock. But glaſs, from the ſmallneſs of its pores, or ſtronger attraction of what it contains, refuſes to admit ſo free a motion; a glaſs rod will not conduct a ſhock, nor will the thinneſt glaſs ſuffer any particle entering one of its ſurfaces to paſs thro' to the other.

36. Hence we ſee the impoſſibility of ſucceſs, in the experiments propoſed, to draw out the effluvial virtues of a non-electric, as cinnamon for inſtance, and mixing them with the electrical fluid, to convey them with that into

the body, by including it in the globe, and then applying friction, &c. For though the effluvia of cinnamon, and the electrical fluid ſhould mix within the globe, they would never come out together through the pores of the glaſs, and ſo go to the prime conductor; for the electrical fluid itſelf cannot come through; and the prime conductor is always ſupply'd from the cuſhion, and that from the floor. And beſides, when the globe is filled with cinnamon, or other non-electric, no electrical fluid can be obtained from its outer ſurface, for the reaſon before-mentioned. I have try'd another way, which I thought more likely to obtain a mixture of the electrical and other effluvia together, if ſuch a mixture had been poſſible. I placed a glaſs plate under my cuſhion, to cut off the communication between the cuſhion and floor; then brought a ſmall chain from the cuſhion into a glaſs of oil of turpentine, and carried another chain from the oil of turpentine to the floor, taking care that the chain from the cuſhion to the glaſs touch'd no part of the frame of the machine. Another chain was fixed to the prime conductor, and held in the hand of a perſon to be electriſed. The ends of the two chains in the glaſs were near an inch diſtant from each other, the oil of turpentine between. Now the globe being turn'd, could draw no fire from the floor through the machine, the communication that way being cut off by the thick glaſs plate under the cuſhion: it muſt then draw it through the chains whoſe ends were dipt in the oil of turpentine. And as the oil of turpentine, being an electric *per ſe*, would not conduct, what came up from the floor, was obliged to jump from the end of one chain to the end of the other, through the ſubſtance of that oil, which we could ſee in large ſparks; and ſo it had a fair opportunity of ſeizing ſome of the fineſt particles of the oil in its paſſage, and carrying them off with it: but no ſuch effect followed, nor could I perceive the leaſt difference in the ſmell of the electrical effluvia thus collected, from what it has when collected otherwiſe; nor does it otherwiſe affect the body of a perſon electriſed. I likewiſe put into a phial, inſtead of water, a ſtrong purgative liquid, and then charged the phial, and took repeated ſhocks from it, in which caſe every particle of the electrical fluid muſt, before it went through my body, have firſt gone through the liquid when the phial is charging, and returned through it when diſcharging, yet no other effect followed than if it had been charged with water. I have alſo ſmelt the electrical fire when drawn thro' gold, ſilver, copper, lead, iron, wood, and the human body, and could perceive no difference; the odour is always the ſame where the ſpark does not burn what it ſtrikes; and therefore I imagine it does not take that ſmell from any quality of the bodies it paſſes through. And indeed, as that ſmell ſo readily leaves the electrical matter, and adheres to the knuckle receiving the ſparks, and to other things; I ſuſpect that it never was connected with it, but ariſes inſtantaneouſly from ſomething in the air acted upon by it. For if it was fine enough to come with the electrical fluid through the body of one perſon, why ſhould it ſtop on the ſkin of another?

But I ſhall never have done, if I tell you all my conjectures, thoughts, and imaginations, on the nature and operations of this electrical fluid, and relate the variety of little experiments we have try'd. I have already made this paper too long, for which I muſt crave pardon, not having now time to make it ſhorter. I ſhall only add, that as it has been obſerved here that ſpirits will fire by the electrical ſpark in the ſummer time, without heating them, when *Fahrenheit*'s thermometer is above 70; ſo when colder, if the operator puts a ſmall flat bottle of ſpirits in his boſom, or a cloſe pocket, with the ſpoon, ſome little time before he uſes them, the heat of his body will communicate warmth more than ſufficient for the purpoſe.

ADDITIONAL EXPERIMENT, *proving that the* Leyden Bottle *has no more electrical Fire in it when charged, than before; nor leſs when diſcharged: That, in diſcharging, the Fire does not iſſue from the Wire and the Coating at the ſame Time, as ſome have thought, but that the Coating always receives what is diſcharged by the Wire, or an equal Quantity; the outer Surface being always in a negative State of Electricity, when the inner Surface is in a poſitive State.*

PLACE a thick plate of glaſs under the rubbing cuſhion, to cut off the communication of electrical fire from the floor to the cuſhion; then, if there be no fine points or hairy threads ſticking out from the cuſhion, or from the parts of the machine oppoſite to the cuſhion, (of which you muſt be careful) you can get but a few ſparks from the prime conductor, which are all the cuſhion will part with.

Hang a phial then on the prime conductor, and it will not charge, tho' you hold it by the coating.—But

Form a communication by a chain from the coating to the cuſhion, and the phial will charge.

For the globe then draws the electrical fire out of the outſide ſurface of the phial, and forces it, through the prime conductor and wire of the phial, into the inſide ſurface.

Thus the bottle is charged with its own fire, no other being to be had while the glaſs plate is under the cuſhion.

Hang two cork balls by flaxen threads to the prime conductor; then touch the coating of the bottle, and they will be electrified and recede from each other.

For juſt as much fire as you give the coating, ſo much is diſcharged thro' the wire upon the prime conductor, whence the cork balls receive an electrical atmoſphere. But,

Take a wire bent in the form of a C, with a ſtick of wax fixed to the outſide of the curve, to hold it by; and apply one end of this wire to the coating, and the other at the ſame time to the prime conductor, the phial will be diſcharged; and if the balls are not electrified before the diſcharge, neither will they appear to be ſo after the diſcharge, for they will not repel each other.

Now if the fire diſcharged from the inſide ſurface of the bottle through its wire, remained on the prime conductor, the balls would be electrified and recede from each other.—

If the phial really exploded at both ends, and diſcharged fire from both coating and wire, the balls would be *more* electrified, and recede *farther*; for none of the fire can eſcape, the wax handle preventing.

But if the fire, with which the inſide ſurface is ſurcharged, be ſo much preciſely as is wanted by the outſide ſurface, it will paſs round through the wire fixed to the wax handle, reſtore the equilibrium in the glaſs, and make no alteration in the ſtate of the prime conductor.

Accordingly we find, that if the prime conductor be electrified, and the cork balls in a ſtate of repellency before the bottle is charged, they continue ſo afterwards. If not, they are not electrified by that diſcharge.

CORRECTIONS *and* ADDITIONS *to the* PRECEDING PAPERS.

PAGE 2, Sect. 1. We ſince find, that the fire in the bottle is not contained in the non-electric, but *in the glaſs.* All that is after ſaid of the *top* and *bottom* of the bottle, is true of the *inſide* and *outſide* ſurfaces, and ſhould have been ſo expreſſed. *See* Sect. 16, p. 16.

Page 6, line 13. The equilibrium will ſoon be reſtored *but ſilently*, &c. This muſt have been a miſtake. When the bottle is full charged, the crooked wire cannot well be brought to touch the top and bottom ſo quick, but that there will be a loud ſpark; unleſs the points be ſharp without loops.

Ibid. line ult. *Outſide:* add, ſuch moiſture continuing up to the cork or wire.

Page 12, line 14. *By candle-light*, &c. From ſome obſervations ſince made, I am inclined to think, that it is not the light, but the ſmoke or non-electric effluvia from the candle, coal, and red-hot iron, that carry off the electrical fire, being firſt attracted and then repelled.

Page 13, line 15. *Windmill wheels*, &c. We afterwards diſcovered, that the afflux or efflux of the electrical fire, was not the cauſe of the motions of thoſe wheels, but various circumſtances of attraction and repulſion.

Page 16, line 21. *Let* A *and* B *ſtand on wax*, &c. We ſoon found that it was only neceſſary for one of them to ſtand on wax.

Page 24, line 12. r. contact, line 24. confined.

Page 25, line 10, for *ſtand* read *hand.*

Page 28, line 2. *The conſequence might perhaps be fatal*, &c. We have found it fatal to ſmall animals, but 'tis not ſtrong enough to kill large ones. The biggeſt we have killed is a hen.

Page 31, line 20. *Ringing of chimes*, &c. This is ſince done.

Page 33, line 22. *Fails after ten or twelve experiments.* This was by a ſmall bottle; and ſince found to fail after with a large glaſs.

Page 40, Sect. 50, 51. *Spirits muſt be heated before we can fire them*, &c. We have ſince fired ſpirits without heating, when the weather is warm.

11 JU.62

F I N I S.